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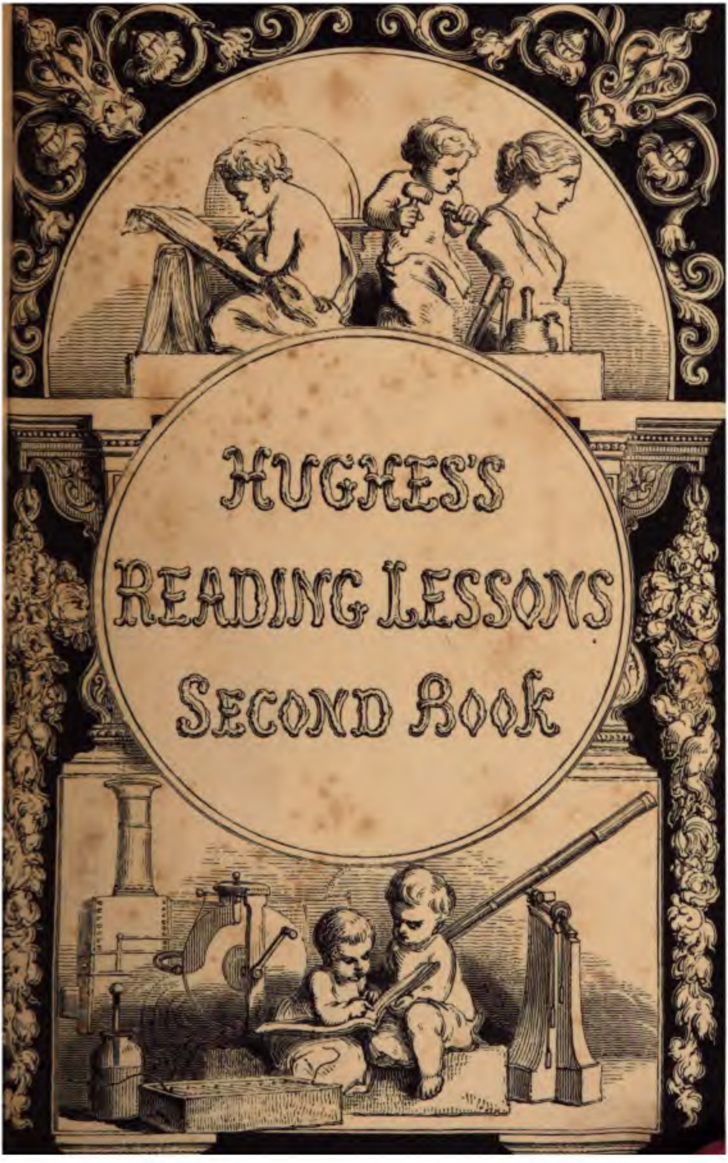

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Royal Naval Schools,
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September 15, 1855.

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LESSON I.

THE USE OF THE SENSES.

> **"He that planted the ear, shall he not hear? he that formed the eye, shall he not see?**
>
> **"He that chastiseth the heathen, shall not he correct? he that teacheth man knowledge, shall not he know?"**

1. All the intimations which we receive directly from external objects are called *sensations*, because they are obtained through the senses, which are themselves termed *organs of sensation*. Our sensations, when noticed by the mind, are also called *perceptions*, and the objects of them or the appearances which we perceive, *phenomena*, which is simply the Greek word for appearances, although in ordinary language the term is applied only to things extraordinary or wonderful.

2. The senses are those of sight, touch, hearing, taste, and smell; to which we might add the muscular sense, or consciousness of an exertion of our muscles; the use of which we will consider in conjunction with that of touch. The organs of sensation are the *eye*, the *surface of the body* generally, but more particularly the extremities of the fingers, the *ear*, the *tongue*, and the *nose*. The structure and mode of action of some of these organs will be briefly described, but our chief object in this chapter will be to inquire into the kind of knowledge which they supply to the mind.

3. So various and important is the information which we are every moment receiving through the senses,

and so accustomed are we to rely upon their accuracy and act upon their intimations, that we are sometimes apt to rest upon first impressions without questioning the power of the organ to give us the kind of knowledge which it *seems* to convey. Hence the old adage, "seeing is believing," and the disposition to think any fact established when we can assert, "I saw it with my own eyes." Now, strange as the statement may appear to those who have not thought about it, we scarcely ever see what we assert that we do. We see what induces the mind to come to a certain conclusion, but whether this conclusion be right or wrong depends quite as much upon our reason as upon the sense of sight.

4. Let us for a moment consider a very simple case. When I say I see a man, what is going on within me is this: a little coloured picture formed in the eye is producing, how we know not, a certain effect upon the mind, and my reason has learned to connect this effect with the presence of the being—man. But the organ, even in a healthy state, can be easily deceived; a well-painted representation produces the same effect upon it as the real object, and impressions upon it can be, and are, reproduced by the imagination, when the real object is absent—as in dreams; so that, in fact, it becomes manifest, on consideration, that seeing is not a sufficient cause for believing in the real existence of what we see, unless we exercise our reason to question the images that appear before us. He who knew what was in man allowed for this infirmity of our nature, when he told Thomas to stretch forth his hand and thrust it into his side, to confirm the sense of sight by that of touch, and to "be not faithless but believing."

5. As sight is the most active and useful, and may be considered the most perfect of all our senses, I shall give another and very striking illustration to show how incapable it is of giving us a real knowledge of things without the assistance of the other senses and reason. It is a case of restored vision recorded in the 'Philosophical Transactions.'

"The boy born blind, upon whom Cheselden so successfully operated, believed, when first he saw, that the objects touched his eyes, as the things which he felt touched his skin; consequently he had no idea of distance. He did not know the form of any object, nor could he distinguish one object from another, however different their figure or size might be: when objects were shown to him which he had known formerly by the touch, he looked at them with attention, and observed them carefully, in order to know them again; but as he had too many objects to retain at once, he forgot the greater part of them; and when he first learned, as he said, to see and know objects, he forgot a thousand for one that he recollected.

6. "It was two months before he discovered that pictures represented solid bodies; until that time he had considered them as planes and surfaces differently coloured, and diversified by a variety of shades; but when he began to conceive that these pictures represented solid bodies, in touching the canvas of a picture with his hand, he expected to find something in reality solid upon it: and he was much astonished when, on touching those parts which seemed round and unequal, he found them flat and smooth, like the rest. He asked which was the sense that deceived him, the sight or the touch? There was shown to him a little portrait of his father, which was in the case of his mother's watch: he said that he knew very well that it was the resemblance of his father; but he asked, with great astonishment, how it was possible for so large a visage to be kept in so small a space? as that appeared to him as impossible as that a bushel could be contained in a pint."

7. From this interesting account we must conclude, that a great deal of the information which our minds now receive readily and immediately from our sensations, the senses themselves are totally incapable of supplying without previous instruction. We have all learned to read, and can, perhaps, recollect the labour which it required to teach the eye to convey to the mind the sound and meaning of printed letters; now it does it instantly, and often almost unconsciously. There are a thousand other things which, without being aware

of it, we have trained our senses to do for us. Indeed none of our faculties are of real use to us, until we have taught them the duties which they have to perform; and the only reason why we do not readily perceive this, is that their education commenced at the earliest period of infancy, when we had not yet begun to reflect, and in after life we find it difficult to distinguish what we have learned to do from what we do naturally.

8. Our senses have been taught in two ways—by each other, and by the reason. A few illustrations will best explain the first. A well-painted representation of a sphere produces the same effect upon the *sight* as a real one, but the slightest *touch* betrays the counterfeit. The sight assists the taste; if a person be blindfolded, and glasses of wine and milk be alternately presented, the taste cannot after a time distinguish one from the other. In like manner, if another of our senses, that of smelling, be suspended by holding the nose, it becomes difficult to distinguish between dissimilar tastes.

The *reason* comes into exercise whenever we ascribe a sensation to its cause, as when without seeing them we say we are listening to the birds, or smell roast beef. That the thrilling notes which we hear are produced by the warbling of birds, or that a peculiar and easily-recognised impression on the olfactory nerves is caused by roast beef, are conclusions of reasoning from a comparison of previous sounds and smells, with the objects which produced them. The sensations in themselves tell us nothing of their causes.

It is of great importance to a workman to ascertain the capabilities of the different tools which he uses, so that he can apply each to that use for which it is adapted. And in like manner it is of great importance to us to estimate rightly the power of each of the senses, which are but instruments of the mind, in order that we may use them with proper caution and most effect.

9. The human eye (fig. 1.) is a small globe fitted into a socket formed in the skull; it is thus guarded against injury by the surrounding bone, and is farther protected in front by moveable curtains called lids. It is held in its place by six muscles, attached at different

points, and can, by their contractions, be turned in any required direction within certain limits; a permanent shortening of one of these muscles causes the defect of vision called squint. The external case of the eyeball, called the *sclerotic coat* (*w w*), is strong, tough, and fibrous for the protection of the delicate interior structure. This outward covering, which is white and impervious to light, is replaced in the front of the eye by an equally strong but transparent substance, called the *cornea;* this is circular and slightly more convex than the other portion of the ball. Through this anterior transparent substance, light from external objects is admitted into the eye. On examining the eye of another person, the cornea will be seen covering all except the white part, and by looking at the side, its raised transparent character can be observed like the glass over the face of a watch. Inside this, and corresponding in position to the face of the watch, is a coloured screen (*i*), called from its varied hue the *iris:* it is this which causes the difference in colour in the eyes of individuals. In the centre of the iris is a small circular opening (*p*), called the pupil, which in a healthy eye always appears a black spot, because when viewing it we are in fact looking into the black chamber of the eye. The use of this iris is to restrict the admission of light from an object to such a portion as shall produce a clear distinct image, and to exclude all that would tend to confuse or would be painful by its excess. To effect this latter purpose there is a beautiful arrangement in its structure, by which it can be drawn back, so as to enlarge the pupil when there is a deficiency of light, or be advanced, and diminish the opening when the light is increased. This action can be observed by any person who steadily views his own eye in a looking-glass, while he alternately advances a light towards his face and removes it.

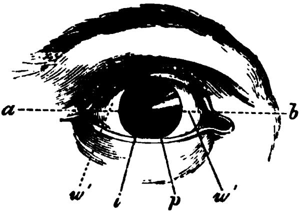


Fig. 1.

10. The interior of the eyeball is filled with three liquids called *humours* separated from each other by delicate membranes. These, shown in figure 2, are called from their nature the aqueous, the crystalline, and the vitreous humours. They serve as a compound optical glass, to collect into a small space the light coming from objects, and so form a minute picture, *m m*, of external scenery. The explanation of the mode in which this is done belongs to the subject of optics, but the same effect, though produced in a different manner, may be seen in the common convex mirror used as an ornament in rooms, and the truth of it may be proved experimentally. If the back part of the eye of an ox recently killed be carefully removed, a minute inverted image of any object to which the pupil is presented, will be seen at the back. The experiment here mentioned shows that up to this point the process of vision is wholly mechanical, and independent of life and volition. The crystalline humour (*c*, *c'*) is the most powerful in its action on light. It is enclosed in a little sack, and is held suspended between the other two by a membrane, called the ciliary process (*b*, *b'*). Loss of vision, arising from the thickening and consequent opacity of this humour, is known as cataract, the only mode of curing which is by removing the defective crystalline lens, and supplying the consequent want of power in the eye by a strongly-refracting glass lens in front.

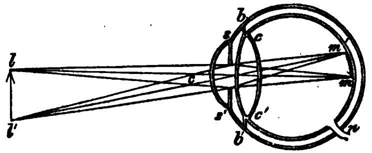


Fig. 2.

11. The part of the inner surface upon which the little picture is formed is covered over with a delicate network, called from its nature the *retina*, and all the rest of the interior is blackened by a lining called the black pigment (*pigmentum nigrum*), intended to prevent any internal reflections of light. The retina is that which brings the mechanically-produced picture (*m*, *m'*) the object (*l*, *l'*) into communication with the nervous

and mental acts of sensation; it is, in fact, a delicate ramification of a nerve called the *optic nerve* (*n*), which enters near the back of the eye. This nerve is not sensitive to light until it has branched out, so that the point at which it enters is called the dark point (*punctum cæcum*). This fact has been referred to, to explain a singular effect noticed by astronomers; if you look intently at a particular star, it sometimes becomes invisible; but by glancing the eye slightly aside, the light of the star falls upon a sensitive part of the retina and produces vision.

12. By the sense of sight we learn the *colours* and *outlines* of bodies, and all the modifications which light undergoes in transmission or reflection. It does not teach us the shape or size or distance of objects, though it greatly assists the mind in estimating all these. From the experience already recorded, of the boy with restored vision, as well as from our own daily observation, we must conclude that a solid body is not by the sight alone distinguishable from a flat surface coloured to represent it. The reason of which is that, in both, the eye perceives the same gradations of colour, and these alone it is capable of estimating. It is not, in fact, in any case the body seen which affects the organ, but *the light* reflected from it; so that if we can by colouring make a flat surface reflect light in the same manner as a solid, it must produce the same sensation.

13. As regards measurement of size and distance, the incapacity of the eye without training is very manifest. We find that an object a foot high placed near the eye has the same effect on the sentient nerve as a man standing at the distance of a mile. It is true we judge of distances and sizes now with tolerable accuracy, because the vision has been educated and is generally informed by the mind, either as to the natural size from which it judges the distance, or the probable distance from which it estimates the size. Gunners who have been well exercised in the use of their weapons can in this way measure the distance of an unapproachable object with considerable accuracy.

14. We must not consider the organ of vision defec-

tive because the knowledge it gives is limited in kind. It is perfect in doing the work which nature has assigned to it, and the Almighty has given to us an intellect to guide its search for information, and other senses to supply different kinds of knowledge. Its tidings are in fact never untrue, but they are often partial, and therefore likely to mislead, unless we understand the exact amount of dependence which can be placed upon its indications. Indeed the limited power of our sense of sight, so far from being a defect, is the source of some of our most refined enjoyments, for to it we owe the glorious art of the painter. Did the eye give a real knowledge of size and distance, the pleasing delusions of painting would be impossible. Nobody could then for a moment imagine that a speck upon a canvas represented a man or a horse. The reality of appearance which produces the charm in viewing a picture could not exist unless shades of colour made the same impression on the organ as a solid form, and decrease of size in perspective gave the full effect of an increase of distance in the object.

15. Having thus shown what the eye can do *of itself* and what it cannot, let us for a moment consider what it can accomplish when trained by experience. It is the most powerful and glorious organ with which the Creator has endowed his creatures. It delights the mind with the order and beauty of the universe, disclosing to us by a single glance an infinity of objects with their innumerable hues and variety of groupings. It penetrates space which we cannot traverse, bringing before us in one view the near and the remote, the large masses and the minute workmanship of nature. It guides our steps in safety, and warns us of danger before its approach. Above all, it opens to the cultivated mind a vast mine of wealth, and source of never-failing delight, in books which contain the learning and wisdom of ages.

16. How pitiable is the condition of a human being who has never enjoyed this wonderful gift of sight, or has been by accident or disease deprived of it! Groping under the noonday sun as at midnight; his world limited

to the grasp of his arms; never beholding the beautiful panorama of nature, or, drawing wisdom from the printed page, and exposed to numberless dangers without a friendly monitor to warn him of their approach. Well may our great poet bewail his loss:—

"——— As the wakeful bird
Sings darkling and in shadiest covert hid
Tunes her nocturnal note. Thus with the year
Seasons return, but not to me returns
Day, or the sweet approach of even or morn,
Or sight of vernal bloom, or summer's rose,
Or flocks or herds or human face divine;
But clouds instead, and ever-during dark
Surrounds me, from the cheerful ways of men
Cut off; and for the book of knowledge fair
Presented with a universal blank
Of nature's works, to me expunged and rased,
And wisdom at one entrance quite shut out."

17. It has been computed that there are in this country 25,000 unfortunate fellow-creatures deprived of the blessing of sight, with "wisdom at one entrance quite shut out." How considerate ought we to be for their unhappy condition! How anxious to open through the other senses an access to their minds! How grateful should we feel to the Father of Good, who has both clothed the earth in beauty and enabled us with unimpaired senses to behold his glorious works!

LESSON II.

THE USE OF THE SENSES—*continued.*

"And the Lord said unto him, Who hath made man's mouth? or who maketh the dumb, or deaf, or the seeing, or the blind? have not I the Lord?"

1. Touch.—This sense is not like the others confined to any particular organ, but is diffused over the whole surface of our bodies. It is, however, much more acute in some parts of the frame than in others, and particularly so at the ends of the fingers, which, by their flexibility, are so well adapted for applying it to the various objects requiring examination. It generally, in conveying

information, acts in conjunction with the *muscular sense*, from which we obtain the notion of weight, solidity, hardness, and softness, and probably of size. We can scarcely feel an object without moving the hand or fingers, so that it is not easy to distinguish between what we owe to each sense. Touch, however, gives us no farther information than that of smoothness, or inequality of surface, and heat and cold. All other sensations commonly ascribed to touch are the impressions upon the muscular sense. *Weight* is that which requires exertion to move, *force* that which overcomes our muscular resistance or calls for its exercise; *hardness* and softness express the degrees of resistance to muscular pressure; and the notion of *size* may result from the different amounts of muscular movement required to pass over unequal spaces.

2. The action of this sense is slow in comparison with that of others, since every part of a surface requires to be felt *in succession* before we can receive the same information which sight gives instantaneously, from its including the whole in one view. If the objects to be studied be large or numerous, this examination in succession instead of at once, as in the case of vision, must render it difficult to get a notion of general arrangement and order; it must also render comparison more difficult, as two objects can rarely be felt at the same time. There are, however, many instances on record of the intellect having accomplished works of great difficulty aided by this sense alone. The blind Saunderson, the friend of Newton, became a professor of mathematics in the University of Cambridge, and lectured upon the motions and order of those millions of the sphere which he could not behold, and upon those laws of light which never, alas! could affect his mind. The roads through Derbyshire were constructed by Metcalf, a blind engineer; the blind traveller Lieut. Holman has visited and described half the countries of the world; and many other instances might be mentioned in which the mind has shown itself superior to bodily infirmities.

3. The delicacy and precision of touch acquired by some workmen, engravers for instance, by constant

practice in their trade even when the hand is hardened by labour, is very remarkable; but the blind, from the sad necessity of their condition, exhibit this improvement of the sense in the most extraordinary manner. Indeed, it has been often remarked, that the deprivation of one sense increases the strength and accuracy of the others; as they are called upon to do additional duty, nature strengthens them for the task. Coleridge mentions the case of a blind man at Hanover, who possessed so keen a touch as to be able to read with his fingers books of ordinary print, if printed, as most German books are, on coarse paper; and an American writer gives an account of an inmate of the Hartford Deaf and Dumb Asylum, who was deaf, dumb, and blind, and therefore almost wholly dependent on the sense of touch, yet had been taught needlework and knitting, and of whom the writer says: "It was occasionally the practice of gentlemen, who, from pity or curiosity, visited her to make trial of her sagacity, by giving her their watches and employing her to restore them to their right owner. They would change their position with regard to her, and each strove to take the watch that did not belong to him; but though she might at the same time hold two or three, neither stratagem nor persuasion could induce her to yield one of them, except to the person from whom she had received it."

4. The instruction of the blind in manual occupations and reading, consists wholly in educating the sense of touch, to supply the deficiency of sight, and as the subject is one of very great interest, the following graphic account of the busy industry which can be guided by the touch alone, is taken from a recent number of the 'Edinburgh Review:'—

"As it is probable that many of our readers have never visited a school for the blind, we will pay a short visit to the great one in St. George's Fields, probably the largest in the world. Of the building we will only say that it is large and imposing in appearance. It contains about 150 pupils, both males and females, of various ages, almost entirely from the indigent class.

5. "We will enter one of the chief work-rooms. In

it, hard at work, we find upwards of forty boys and men, all totally blind, making basket-work of every possible size and description, from the finest and most delicate of dinner-mats to the gigantic ark of unpeeled osier for packing swans for a journey across the North Sea. The workers are all cheerful, nay, in most cases, merry. Baskets, flower-stands, chairs, and screens, in short, all kinds of wicker-work, are here made by the thousand every year. The little boy on the left is a new-comer. He is taking a first lesson from the foreman, and learning to split the osiers. In a month from this time he will be able to make a rough market-basket. Two months ago he sat moping in a dark corner of a fisherman's cottage in Cornwall, in forlorn helplessness. Since then, mind and body have begun to revive; he is now bright, cheerful, and intelligent; he can now use his limbs, and begins to find out that he has a mind, ay, and much more, a soul within him: he has mastered his alphabet, and begun the good habit of saying daily prayers with his companions, and hearing God's Word read. His education has commenced, he is learning to think, he is waking up to a new life.

6. "Look where we will, the work goes busily and deftly on, as if all the workers had the best of eyes. They sort the osiers, pull them, split them, arrange them for use, if necessary point them, and chip off stray ends of obnoxious twigs with a sharp knife. Enter the shoe-shop, and we are impressed with the same conviction, and judging only by the work done, we decide at once that the workman must have sharp eyes; hammering, cutting, sewing, going on as cleverly and quickly as among the most clear-sighted set of Crispins. In this room are made shoes for the whole 150 pupils. Enter the mat-shop, look at that mountain of mats of all colours, asperities, and sizes; all made by more busy workers whose eyes never saw what their hands so diligently toiled at.

7. "That huge pile on the right is chiefly of coloured rugs decked with brilliant borders, wreaths of flowers, and patterns of all hues and sizes. It seems impossible that they are the work of the blind. But they can be,

and are made in this very shop. The man working at a loom in the corner is making a rug, with a brilliant crimson scroll at either corner on a dark ground. His wools of different colours are given to him by the foreman in a certain order; and these he himself arranges by his side, easily within reach, also in a certain order. But how shall he know the pattern of the future rug? No possible description, even if the busy foreman could afford time for it, could explain the intricacies of that scrollwork. It must be exactly done, too, for it is to match a carpet; every twisted leaf of that rare flower and that curious branch, which grow only in carpetland, must be accurately copied, or Mr. Brown's critical eye will be offended as he stands in a judicial mood on the border where the land of drugget commences. How then is our rug-maker to follow a pattern he has never seen, in colours of which he has not the faintest notion? Look at him; he is consulting his guide. It is a thin smooth sheet of deal, mathematically divided by cross-bar lines, scratched into the surface. At certain points of intersection nails are inserted; some deeply, some lightly, others almost buried in the wood, barely catching the eye. The blind weaver is reading them with his finger. They describe to him the pattern his eye never saw. Observe that some nails have large dropsical heads; others are headless; a third kind are dying of atrophy, mere pins; a fourth class wear college caps; and a fifth are but ignominious brads.

"As his finger follows the line of brads, it is to him as a waved line, circle, or square; it may be of green or black, or what not; but whichever it be, he feels at once the exact point where to insert the necessary change of colour. Each nail tells its own story, every change of colour, and every new line of march; and this story the blind weaver reads with his fingers' ends. Of course it is not every pupil that attains this degree of skill and dexterity. Some never obtain it. It is the reward of many years' patient assiduity on the part of teacher and pupil. It is not to be wondered at that comparatively few attain so great an amount o skill, but that a single blind pupil ever thus masters a weaver's difficult trade."

8. The delusions of touch are not numerous: it is generally sure, though slow in its conclusions, and so we constantly appeal to it from the other senses. Isaac, when "his eyes were dim, so that he could not see," and a doubt was raised by the speedy return, and the voice of his son, *felt* the hand and the neck of Jacob, though by the fraud practised upon him this sense also was deceived, so that he decided "the voice is Jacob's voice, but the hands are the hands of Esau." That it can sometimes be deceived without actual fraud, is however manifest from a very simple experiment. Cross the first and second fingers of the hand, and place them so crossed upon a pea or any other small round body, you will at once feel *two!* This mistake of the touch, no doubt, arises from the fact that in the natural position of the hand, and that to which we are consequently most accustomed, it would require two such bodies to touch those parts of the fingers which are by crossing brought into contact with one. The actual amount of heat or cold in a body also can never be estimated by the touch, because it never tells more than the difference in condition as to heat of our body and the substances with which it is brought in contact, and not always even this. We feel a blanket warm on a winter night, and the sheets on entering a bed very cold, yet a thermometer would show that they are of precisely the same temperature. For the cause of this difference in feeling we must refer to the article on Heat. It is sufficient here to mention it as a delusion of the organ of touch.

9. HEARING.—The organ of this sense (fig. 3), like that of sight, is double, consisting of the two ears situated one at each side of the head. The human ear is made up of a great number of minute parts, some of which are of very intricate construction, and the uses of which, in facilitating the perception of sounds, are not so well understood as those of the different parts of the eye. We shall not here attempt more than a general sketch of its form and structure, and the mechanical operations performed by it in conveying

the impressions produced, to the auditory nerve, beyond which our knowledge does not extend. Projecting from each side of the head and of a beautiful shell-like shape, is the *auricle* (*a*, *a*,), or external ear, the purpose of which seems to be, to collect a larger extent of auditory vibrations than a simple aperture could. The convolutions of the auricle terminate in a passage (1), leading in a slightly-curved direction in through the bone of the skull. Stretched tightly across this passage, so as completely to close it, is the membrane of the tympanum, commonly called the *drum* of the ear, because it resembles the strained head of that instrument. Up to this point the process of hearing is plain, the auricle, like the broad estuary of a river, collects the sound-waves into a narrow funnel, in order that they may with intensified force beat against the drum and communicate a vibration to it.

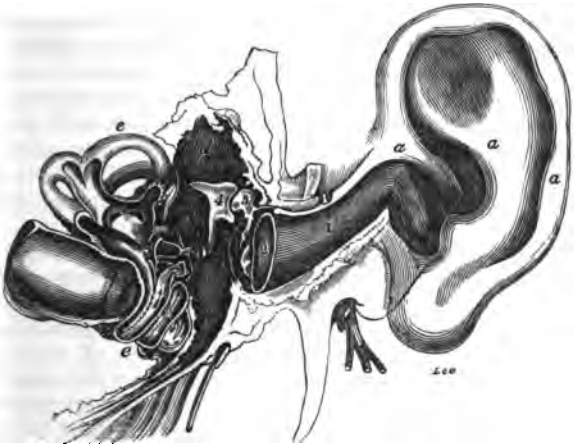


Fig. 3.

10. Behind the membrane, and thus separated from the outward ear, is an open space called the tympanum (*d*), resembling somewhat the inside of the drum. Leading into the tympanum is a passage called the

Eustachian tube, passing down to the back of the mouth, by which means air can be admitted into the ear, and connected with the membrane are three small bones called the hammer (*malleus*) (3), the anvil (*incus*) (4), and the stirrup (*stapes*) (5). These seem to perform a very important part in the transmission of the vibrations, and have also the power of straining or relaxing the membrane, and so fitting it to receive different kinds of vibration. The innermost of these bones, the stirrup, is exactly fitted to an opening called the *fenestra ovalis*, which leads into the inner ear, and across which a second vibrating membrane is stretched. Any accident to this part of the ear causes deafness, although a person can hear after the drum of the ear has been broken. Beyond this is a construction so involved that it has got the name of the labyrinth (*e*, *e*), and although its anatomy has been carefully studied, and the various parts composing it classified and named, the purposes which they serve are still more a matter of surmise than certainty.

11. Sounds in all their varieties and modifications are the objects of this sense. It assists in the preservation of the animal frame, by serving as a monitor of danger. In some classes of animals it possesses great acuteness; and many of us have felt in the darkness of night, at periods when danger was apprehended, how the sense of hearing has been sharpened to an almost painful degree.

The interchange of thought between rational beings is, however, the great purpose for which they have been endowed with this sense. It "speeds the soft intercourse from soul to soul," enables us to convey to others our wishes, to make known our wants, and communicate our feelings. It increases the desire for social union, by the pleasures of conversation, and strengthens social order and discipline, by the readiness and distinctness with which commands are received. Doubtless the deaf have means of communicating thoughts by visible signs, or by the touch; but how much of their advantages do they owe to the instruction of those who have been accustomed to vocal sounds, and how tedious and imperfect are their communications at the best! The sound of a human voice, of a man speaking to his fellow-man, excites feelings and sympathies which can never be called forth by the printed page.

12. The delight which we receive from the harmonious periods of the orator, the rhythm of the poet, or the delicious "concord of sweet sounds" with which nature soothes the ear in the melody of the grove, and the refined and ennobling pleasure which is afforded through our sense of hearing by the art of the musician, are proofs of the Divine benevolence, which has not merely made our senses useful, but has constituted them to be a constant source of satisfaction and delight.

13. All our great poets have been very sensitive to the pleasures of the ear. Milton, in that poem which is itself music, thus speaks of the sounds of early morning:—

"To hear the lark begin his flight,
And singing startle the dull night,
From his watch-tower in the skies,
Till the dappled dawn doth rise;
Then to come, in spite of sorrow,
And at my window bid good morrow,
Through the sweetbriar or the vine,
Or the twisted eglantine:
While the cock with lively din
Scatters the rear of darkness thin;
And to the stack, or the barn door,
Stoutly struts his dames before:
Oft listening how the hounds and horn
Cheerly rouse the slumb'ring morn,
From the side of some hoar hill,
Through the high wood echoing shrill.

* * * *

While the ploughman near at hand
Whistles o'er the furrow'd land,
And the milkmaid singeth blithe,
And the mower wets his scythe,
And every shepherd tells his tale
Under the hawthorn in the dale."

Again of artificial music:—

"And ever against eating cares,
Lap me in soft Lydian airs,

Married to immortal verse,
Such as the melting soul may pierce,
In notes, with many a winding bout
Of linked sweetness long drawn out;
With wanton heed and giddy cunning,
The melting voice through mazes running;
Untwisting all the chains that tie
The hidden soul of harmony;
That Orpheus' self may heave his head
From golden slumber on a bed
Of heap'd Elysian flowers, and hear
Such strains as would have won the ear
Of Pluto, to have quite set free
His half-regain'd Eurydice."

14. Our sense of hearing is not exposed to many deceptions, unless when our imagination adds some fancied accompaniment to the sound which we hear. It does not directly give us any information as to the position of its source, though it is by distance and position modified in intensity and tone; and it is by a power over his organs of speech, enabling him to imitate these changes of intensity and tone, that the ventriloquist effects his illusions.

15. Taste.—The organ of this sense is the surface of the tongue, and the great purpose which it was intended to serve, was to enable us to distinguish between articles fit for food and sustenance, and those which are innutritive or injurious. In this necessary judgment, animals are much aided by the smell; and it will be found that when this latter sense is suspended, as often occurs during a heavy cold, the sensations of taste are much weakened, and we can less accurately distinguish one flavour from another. Like the touch, it gives us no information without actual contact, and is very limited in its functions. It is of extreme importance in guarding against the reception into the stomach of substances injurious to the animal frame, and a source of innocent pleasure if our appetites be indulged with moderation, if we eat to live, and not, like the glutton, live to eat.

16. Speaking of the pleasures of the palate, Dr. Paley says: "Assuming the necessity of food for the support

of animal life, it is requisite that the animal be provided with organs fitted for the procuring and digesting of its food. It may also be necessary that the animal be impelled by its sensations to exert its organs. But the pain of hunger would do all this. Why add pleasure to the act of eating, sweetness and relish to food? Why a new and appropriate sense for the perception of the pleasure? Why should the juice of a peach, applied to the palate, affect the part so differently from what it does when rubbed upon the palm of the hand? This is a construction which, so far as appeared to me, can be resolved into nothing but the pure benevolence of the Creator."

17. Smelling.—This may be considered to perform the same duties for the taste that the sight does for the touch. It gives an intimation at a distance, of substances dangerous or useful. Thus, in the great majority of hunting animals, it is the guide by which they are enabled to track their prey, and so procure the food necessary for their subsistence. It not only informs us of the wholesome state of the food which is placed before us, but also gives us warning of the presence of unhealthy vapours or gases, which, by their insidious action on our organs, would cause disease, and cautions us to remove from our dwellings all filth and corruption, which bear in them the seeds of death. Unhappily, too often its warnings are neglected, until an epidemic breaks out, and filth exhibits itself in pestilence.

Edward Purcell.

Physical Geography.

BY EDWARD HUGHES.

LESSON I.

SURFACE OF THE LAND.

"Before the mountains were brought forth, or ever thou hadst formed the earth and the world, even from everlasting to everlasting, thou art God."

1. The great land masses of the globe differ widely not only in the details of their horizontal form, but also in the vertical configuration of their surfaces. Th

height of the land is generally measured from the level of the sea; in some places it rises only a few inches above this level, and in other places to several thousand feet. Those portions which are not more than 500 or 600 feet above the sea-level are called by geographers *Lowlands*, and those which attain a greater elevation are termed *Highlands*. These depressions and elevations constitute the two grand divisions of land upon the earth's surface; but the latter, for the sake of more minute description, has been subdivided into Upland Plains, Table Lands, or Plateaux, and Mountain Chains. We shall now proceed to consider the first division, namely,

2. *Lowland Plains.* — These consist of extensive tracts of low-lying land, which in some places are only slightly elevated above the sea-level, and in others considerably below it. Some of these spread out into monotonous dead flats, others present a gently-waving surface, and others again are more prominently undulated. They are known in the Old World under the various denominations of steppes, heaths, marshes, tundra, and deserts; and in the New World are called savannas, prairies, llanos, and pampas. These low plains cover about two-thirds of the surface of Europe and America, and about one-third of Asia and Africa.

3. *Upland Plains, Table Lands, or Plateaux,* properly so called, comprise the elevated plains which rise abruptly from the general level of the surrounding country. Sometimes they appear to rise out of or to be placed upon one another; and when viewed from one side, present the appearance of a series of platforms or terraces, as on the eastern slope of the Cordillera and the southern slope of the mountains at the Cape of Good Hope. The term is also sometimes applied to the broad and horizontal or gently-sloping top of an immense mountain. The most extensive of this latter class are the elevated table lands of Tibet, and the plateau of the Deccan in Asia, that of Spain in Europe, and the highland of Southern Africa. In North America there is the lofty table land of Mexico, and in

South America those enclosed by the Andes. The grandest example of plateau on the face of the globe is that of Central Asia, enclosing Chinese Tartary and Tibet. It is at a height of several thousand feet above the level of the sea, and is supported by immense ramparts of lofty mountains. Figure 1 shows the relative position of this table land. 1, is the level of the Black Sea; 2, the height of mount Ararat; 3, the Caspian; 4, Tartary; 5, the Bolor Tagh; 6, the great plateau of Crim Tartary; 7, the Yang-ling; 8, China; and 9, the Pacific Ocean.

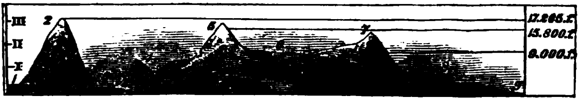


Fig. 1.

4. ***Mountains*** are the loftiest prominences on the surface of the globe. When a mountain extends for a considerable distance without interruption, it is called a *ridge;* and when several ridges are connected in one line they are called ranges or chains. Mountains, when clustered together, are termed *groups;* and if they form the centre from which several chains diverge, they are called a knot.

5. The loftiest points or peaks of a mountain range vary in form, according to their height, and the nature of the rock of which they are composed. If composed of hard rock, they generally attain a great elevation, and are usually rugged and sharp; peaks of this kind are often called horns, teeth, needles, &c., from a fancied resemblance to one of these objects. When mountains are composed of softer rock, they are comparatively less elevated, and the peaks are less sharp and jagged. The fragments accumulated around their bases and sides render them less steep, and they often have a rounded appearance like a bell, a dome, a head, &c., and receive a corresponding name.

6. The declivities of mountains are generally long and gentle on one side, but sometimes rapid and even

steep on the other. The steeper declivity is generally towards the sea, but when the system consists of several chains, the steepest side is often towards the central chain. Sometimes a mountain chain descends by one regular slope into the surrounding lowlands, but more frequently by a succession of stages or terraces, divided by secondary ranges parallel to the principal chain.

7. *Direction of Mountain Systems.*—The mountains upon the earth's surface may be arranged into two grand divisions, which lie in the direction of the greatest length of the continents. The system in the Old World, which attains in its highest part an elevation of 28,000 feet, stretches north-north-east by south-south-west for nearly 9,000 miles quite across the continent. The system of the New World, which nowhere reaches a greater elevation than 23,200 feet, extends north-north-west by south-south-east, from the 70th parallel of north latitude to the 60th parallel of south latitude, a distance of nearly 9,000 miles.

8. In the Old World the vast mountain system may be traced from the north-west shores of Asia to the western shores of Europe and Africa. From Behring's Strait the mountain range of Aldan or Stanovoi proceeds southward, and is connected to the Yablonoi, which, continuing to the south, meets the long chain of the Altai, on the northern side of the immense plateau of Central Asia. The Khin-ghan, Ala-shan, and Yang-ling unite and form the eastern wall of the great plateau. The latter ridge sends off two large spurs called the Pe-ling and Nan-ling mountains, which run in an east and west direction through China. On the summit of the plateau two extensive and nearly parallel chains run from east to west, that on the north is called the Thianshan, and that on the south the Kuen-lun. The southern wall of the plateau is formed by the vast chain of the Himalaya, which comprises the loftiest projections on the surface of the globe. On the western side are the Bolor Tagh range, and the mountain knot of the Hindoo Koosh. This zone of highland is continued

westward by the Soliman mountains, the plateau of Iran, the Elburz mountains, the Caucasus, the Taurus, and the plateaux of Armenia and Arabia to the western shores of Asia.

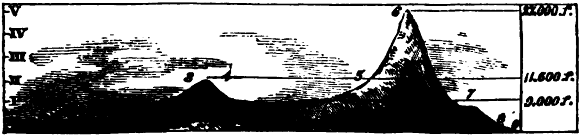


Fig. 2.

Figure 2 represents a section of the Old World, from the Arctic to the Indian Ocean. 1, is the level of the Arctic Ocean; 2, the plains of Siberia; 3, the Altaian Mountains; 4 and 5, Crim Tartary and Tibet; 6, the Himalaya Mountains; 7, Nepaul; 8, India; and 9, the Bay of Bengal.

9. In Africa the Atlas range occupies the region between the Sahara and the Mediterranean, rising gradually from the east towards the west until it terminates in a mountain knot in Morocco, at an elevation of 15,000 feet. Northward the band is continued into Europe by the elevated ridges of the Balkan, thence westward through the various ranges of the Dinaric, Noric, Julian and Tyrolese Alps to the culminating points, Mount Blanc and Mount Rosa, of the great Alpine chain.

10. In Central Europe are the Carpathian mountains, westward of which are the Hercynian, and to these succeed the Vosges. West of the Alps, and to the south of France are the Cevennes, which unite with the Pyrenees; these again are prolonged into the Cantabrian mountains. South of these, several parallel ridges cross the elevated table land of the Spanish peninsula, gradually diminishing in elevation until they terminate in headlands, which form the most westerly points of continental Europe.

11. Thus we see that a great belt of highland traverses the whole extent of the old Continent from the north-north-east point of Asia, on the shores of the

Pacific, to the south-west of Europe, on the shores of the Atlantic Ocean.

The highlands and mountain ranges which seem to be unconnected with the mountain system which we have thus traced are in Asia, the table land of the Deccan in India, and the ranges which surround it. In Europe, the Ural mountains and those of the Scandinavian peninsula. In Africa, the great table land which is supposed to occupy the whole of its southern regions, with the ranges which flank it on all sides.

12. In the New World the mountain systems are much more simple than in the Old. The great American ranges begin north of the Mackenzie river, about the 70th parallel, and extends south-eastward, receiving the successive names of the Rocky or Chippewan mountains, Oregon mountains, mountains of Mexico, which enclose numerous table lands, and occupy the country as far as the Isthmus of Panama, where they are interrupted by low plains stretching almost from sea to sea.

From this narrow strip of land, the Andes rise in bold rugged masses to the region of perpetual snow, and form the largest and loftiest mountain system in the New World. The chain extends southward for about 4,500 miles, enclosing between its parallel chains rich and populous table lands, and at its southern extremity splits into separate mountain masses, the last of which is the naked rock of Cape Horn, the southern point of Hermit Island.

13. Besides the continuous chain now traced, there are—in North America, the Californian mountains, which skirt the north-west coast, and the Appalachian or Alleghany chain, which runs north-east through the United States; and in South America the ranges of Parime and Brazil.

The mountains of Australia, so far as they are at present known, extend near the coast, and lie in a meridional direction. The highest are the Warragong mountains or Australian Alps. Northward of these there is an extensive chain along the eastern coast, the explored portions of which are called the Blue Mountains and the Liverpool range.

14. *Earthquakes and Volcanoes.*—An earthquake is a sudden upheaval, depression, or fracture of a limited area of the earth's surface: all of which movements are produced sometimes by a slight shaking or tremulous motion of the earth, at other times by a violent convulsion, and at others by a rocking or heaving of the surface. The origin of these phenomena is to be sought for in the fires, fluids, and gases which are in the interior of our planet.

The concussions, which rapidly succeed each other, are distinguished as *vertical*, *horizontal*, and *circular* oscillations. The vertical or mine-like explosion acting from below upwards was shown in a most striking manner at the overthrow of Riobamba in Quito, in 1797, when the bodies of many of the inhabitants were thrown upon a hill several hundred feet high. The horizontal vibration is a roll or undulation which in itsprogress causes an alternate rise and fall in the earth's surface. The circular (or gyratory) commotion is the most rare, and at the same time the most dangerous. It has been known to distort walls without overthrowing them, to inflect parallel rows of trees, and in fields having two sorts of cultivation, it has caused the crop of one to take the place before occupied by the other.

15. The shocks come on with a deep rumbling noise, like that of a carriage over a rough pavement, or with a violent explosion resembling the discharge of artillery, or the bursting of a thunder-cloud. Single shocks seldom last more than a few minutes, but they frequently follow one another at short intervals for a considerable length of time. During these commotions chasms have been made in the ground, from which smoke, flame, stones, or water, have sometimes been discharged. In violent earthquakes whole cities have been overwhelmed, islands sunk, and new ones raised; the courses of rivers changed, and seas caused to overflow the land.

16. *Volcanoes* are openings in the earth's surface, from which smoke, flames, stones, lava, and other substances are ejected. They are merely the channels of upward communication from subterranean fires, and

must be considered the safety-valves of the countries adjacent to them, as earthquakes always occur at a distance from active volcanoes. The eruptions in most instances occur only occasionally; centuries, as in the case of Vesuvius, having elapsed between successive explosions. In some cases the eruptions do not continue for any great length of time, and in others a slow action is constantly going on with periods of increased energy at intervals of months or years.

17. Volcanoes are termed *active* when at times they send forth streams of melted rocks, mud, showers of ashes, jets of steam, or gas. They are called *extinct* when they have ceased to emit such matters within the records of history.

Volcanic eruptions are generally preceded by earthquakes, and both must be considered the effects of the same internal heat produced by the agency of chemical processes going on in the interior of the earth. The number of active volcanoes upon the surface of the globe is about 270, nearly 190 of which are upon the islands or shores of the Pacific Ocean.

18. Earthquakes and volcanic bursts are usually preceded by peculiar atmospheric phenomena, such as sudden gusts of wind interrupted by dead calms, violent rains at unusual seasons, and the evolution of electric matter, gases, and vapour from the soil. The waters also of the ocean and lakes frequently present an unusual agitation.

The volcanic districts in which these phenomena occur

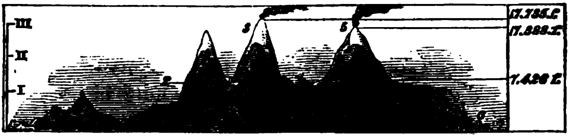


Fig. 3.

are, with the exception of that of Central Asia, situated along the shores of the great continents, or on the adjacent islands, and may be arranged into four distinct systems, namely, 1. The volcanic system of the Pacific;

2. The system of the Atlantic; 3. The system of the Indian Ocean; and 4. The system of Central Asia.

The great volcanic peaks of South America are shown in the accompanying figure (3), which represents the level of the New World, from the Gulf of Mexico to the Pacific Ocean. 1, is the level of the Pacific; 2, the City of Mexico; 3, Mount Pococatapetl; 4, the town of Peubla; 5, Volcano of Arizaba; 6, town of Vera Cruz; and 7, the Gulf of Mexico.

THE WORSHIP OF NATURE.

The ocean looketh up to heaven,
As 'twere a living thing;
The homage of its waves is given
In ceaseless worshipping.

They kneel upon the sloping sand,
As bends the human knee,
A beautiful and tireless band,
The priesthood of the sea!

They pour the glittering treasures out
Which in the deep have birth,
And chant their awful hymns about
The watching hills of earth.

The green earth sends its incense up
From every mountain shrine,
From every flower and dewy cup
That greeteth the sunshine.

The mists are lifted from the rills,
Like the white wing of prayer;
They lean above the ancient hills,
As doing homage there.

The forest tops are lowly cast
O'er breezy hill and glen,
As if a prayerful spirit passed
On nature as on men.

The clouds weep o'er the fallen world,
E'en as repentant love;
Ere to the blessed breeze unfurled
They fade in light above.

The sky it is a temple's arch;
  The blue and wavy air
Is glorious with the spirit-march
  Of messengers at prayer.

The gentle moon, the kindling sun,
  The many stars are given,
As shrines to burn earth's incense on,
  The altar-fires of Heaven.

John G. Whittier.

LESSON II.

HYDROGRAPHY.

> "All the rivers run into the sea; yet the sea is not full: unto the place from whence the rivers come, thither they return again."

The waters variously distributed over the face of the globe may be conveniently considered under the distinct heads of rivers, lakes, and seas.

1. *Rivers.*—Rivers are volumes of water flowing in open channels through the land. They are formed by the confluence of brooks, rivulets, or streams, whose waters they discharge into the ocean, lakes, or marshes. The sources of rivers are generally a number of springs or rills which issue from the base of a declivity, the foot of a hill or mountain, or sometimes from a lake or swamp.

Small rivers generally unite and form one *principal river*, and those which increase its waters are called with respect to it *affluents* or *tributaries*, and sometimes *feeders* or *branches*. The country drained by a river is called its *basin*, through the lowest part of which the river descends in a cavity called its *bed* until it reaches its termination which is called its *mouth*. The *course* of a river is the line of descent in which it flows.

2. Most large rivers have their sources, or take their *rise*, as it is termed, in lofty mountains or elevated table lands. In descending from these regions they present a great difference in the rapidity of their courses, according to the form and inclination of the channels, and the quantity of water contained in them; and hence the whole length of such rivers is divided into *upper*, *middle*, and *lower* courses. The ridge-line formed by

the intersection of slopes sending their waters in opposite directions is called the *watershed* or *water-parting*; this line of sources is not however always on mountains or highlands, but sometimes in swamps and marshes.

The length of a river from its source to its mouth, including all its windings, is called its *development.* The *magnitude* of a river depends upon the extent of its development, the area and rain-collecting character of its basin, the number of its feeders, and its connexion with snow-clad regions.

3. When a river splits into two distinct branches it is said to *bifurcate*, or form a fork. Sometimes the opposite to this happens when the basins of rivers are so nearly on a level that their waters flow together; thus the Casiquiare, a large navigable stream, unites the Orinoco with the Rio Negro, a branch of the Amazon.

Rivers which terminate on low coasts are so checked by the counter force of the sea that they generally deposit at their mouths the sand and mud which they have held in suspension, and thus *bars* or *sand-banks* are formed, which render the entrance shallow. In such cases a river is sometimes divided into numerous channels enclosing portions of land of a triangular form, which are called *deltas* from their resemblance in shape to the Greek letter Δ.

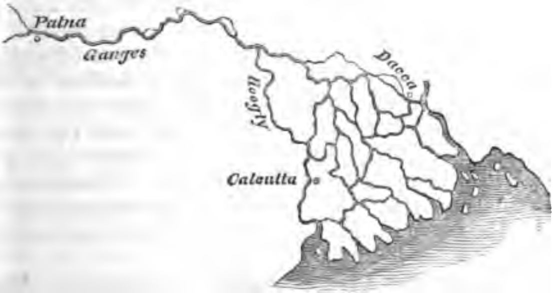


Fig. 4.

Fig. 4 represents the singular interlacing of branches formed by the Ganges in the alluvial soil at its mouth

The low marshy district through which they run, is called the Sunderbunds.

4. Most rivers have periodical inundations, and overflow the countries which are adjacent to their banks; the period of inundation depends upon the time of the great falls of rain in their basins, or upon the melting of snow and ice in the mountain regions in which they have their sources. In the Torrid Zone the rains of the wet season descend in such torrents that they soon fill not only the beds of the streams, but almost every valley; and in many places drive the inhabitants to the highlands. In the Temperate Zone, the floods are less uniform, varying not only with the climate, but with the changing character of the year, the proximity of mountains, the fall of rain or snow, and the occurrence of thaws or storms. In the North Frigid Zone the rivers are frozen, and become solid during winter.

Those rivers which have a part of their lower course influenced by the ebb and flow of the tide are called *tidal rivers.*

5. Rivers are arranged into the following two great classes, viz.:—

1. Oceanic rivers, which discharge their waters directly into one of the four great oceans, or their branches.

2. Continental rivers, which are confined exclusively to the Continent, and discharge themselves into lakes or lose themselves in the sand of their own channels.

6. *Lakes.*—A lake is a collection of water of greater or less extent, contained in a cavity or hollow of the earth, either wholly surrounded by land, or having direct communication with the ocean or seas by means of rivers. The former are almost invariably salt, and the latter may be termed stream lakes. These bodies of inland waters may be classed under four heads, viz.:—

1. Those which have no outlet, and receive no running water.

2. Those which have an outlet, but receive no superficial running water, and are consequently fed by springs.

3. Those which receive and discharge streams of water. These are by far the most numerous class.

4. Those which receive streams, but have no visible outlet, as the Caspian Sea and Lake Aral.

Lakes are also sometimes divided into fresh-water lakes and salt-water lakes.

7. The term *chain* is applied to lakes, when they are disposed in a line, communicating with one another; and *cluster*, when several small ones are grouped together; and *lake region*, to the country in which they are numerous and of considerable extent. North America contains the largest lakes on the globe, particularly the chain of Superior, Huron, Michigan, Erie, and Ontario.

8. The lakes of flat countries, such as the lowlands of Northern Germany, are very shallow, but those of mountainous regions occupy deep clefts or basins in the rocks on which these countries are based. Some of the lakes of the Alps, Norway, Sweden, Scotland, and Finland, are of great depth.

Some lakes are considerably depressed below the level of the sea, as the Caspian, which is from 70 to 90 feet lower than the Mediterranean; and the Dead Sea in Palestine, which is 1,312 feet below the same level. Others again are greatly above the sea-level, as the Swiss lakes, and Lake Titicaca in Peru, which is at an elevation of 12,847 feet.

9. *Oceanic Movements.*—The extent and distribution of the oceanic waters having been fully described in a former chapter, we shall here consider some of the movements to which they are subject. These are of three kinds, namely, *waves*, *tides*, and *currents*.

Waves are produced by the unequal pressure of the air upon contiguous portions of the surface of the ocean. The parts most pressed upon sink beneath the natural level, while those least pressed upon rise above it; when the former portions have sunk to a certain depth, and the latter risen to a certain height, their motions are reversed, and thus a reciprocating motion is produced, and a series of ridges and hollows formed, which are called *waves*. The waves of the ocean are generally raised by the action of the wind upon its surface, and the height of such waves depends in a great measure upon the depth of the water in which they are produced.

10. *Tides* are the regular alternate risings and fallings of the waters of the ocean and of bays, rivers, &c., which communicate freely with it. These elevations and depressions, which generally occur twice in the course of a lunar day, or 24h. 50m. 28s. mean solar time, are produced by the attraction of the moon, combined with that of the sun, but they are chiefly regulated by the former body. The moon by her attraction raises the waters of the ocean under her, and at the same time causes an elevation of the waters on the opposite side of the earth. The sun by his attraction raises similar waves, but in consequence of his great distance they are of less extent. When the sun and moon are in conjunction and opposition, that is, at new or full moon, their combined actions produce spring tides, and when the moon is in quadrature, neap tides are produced.

The time of high water, like the moon's rising, is about 50 minutes later every day. The interval between the times of the transit of the moon and the times of high water on full and change days is called "Establishment of the Port," and when this is known at any seaport the time of high water on any other day can, in most cases, be ascertained. If lines be drawn upon a map connecting those points upon the earth's surface at which the "Establishment," or time of high water, is the same, a series of lines will then be traced called *co-tidal lines*.

11. The attraction of the sun and moon is felt most at the equator, and the height of the tides diminishes in receding from that circle, until near the poles they are scarcely perceptible. In open situations, as the islands of the Pacific Ocean, the tides rise at regular periods to the height of one or two feet; but when the tide-wave enters a bay, or rushes through a narrow channel, the time of high water is much varied, and the height greatly increased. In the British Channel the tide sometimes rises to 40 or 50 feet, and at the entrance of the Channel to 30 feet. In the Bay of Fundy it rises to 60 feet, and often so rapidly that cattle feeding on the shore have been drowned before they could escape. In inland seas

and lakes,—as the Black Sea, the Baltic, and the Caspian, there is no perceptible tide, and in the Mediterranean it is inconsiderable. In the open ocean, near the equator, the tides follow the apparent motion of the moon from east to west, but in the north temperate zone their direction and velocity are greatly varied and modified by the outlines of the shores.

12. *Currents.*—The waters of the ocean are perpetually moving in currents which appear to complete the circuit of the globe. Some are *permanent*, others are *variable*, and change with the seasons, winds, or tides.

13. *Currents of the Pacific Ocean.*—The Antartic drift current, which is caused by the melting of ice and the prevailing south-west winds, flows from the south pole. It first sets from south to north, but is gradually deflected eastward towards the coast of Chili. About the meridian of 80° W. it divides, one part flowing south to Cape Horn, the other northward along the western coast of South America, where it receives the name of the Peruvian Current, a subdivision of which is called Mentor's Counter-current. The Peruvian Current favours the voyage along the coast to such an extent that vessels sail from Valparaiso to Callao (the port of Lima), a distance of more than 1,600 miles, in eight or nine days, while several weeks, and in some cases even months, are spent in the return voyage. Between Lima and Cape Blanco the current suddenly leaves the coast, and mixes with the general rotation or Equatorial Current. Near the Galapagos Islands the cool current coming from the southward meets a warmer stream from the neighbourhood of the Bay of Panama. Of these currents Captain Fitzroy observes that, "in some places they run three, four, or even five miles an hour, generally but not always, to the north-west. On one side of an island the temperature of the sea is sometimes found to be near 80°, while on the other side the water is at less than 60°."

14. *The Equatorial Current of the Pacific* is the movement of the waters of the Pacific from east to west. The stream begins to be felt at a distance from the con-

tinent of about 10 ° W. long.; thence it runs westward, and following the impulse of the trade winds, flows, according to Humboldt, at the rate of from 7 to 8 miles in 24 hours. The southern limit of this mighty sea-stream coincides with the parallel of 26° S., while its northern border may be reckoned at 24° N.; so that the oceanic waters move in a westerly direction over a space of 50°, or nearly one-third part of the distance from pole to pole. Between latitudes 5° and 100° N. there is a current flowing in the opposite direction, called the North Equatorial Counter-current.

15. *The Cape Horn Current* flows round the Cape towards the Falkland Islands, and is gradually lost in the Atlantic Ocean.

The Mexican Coast Current flows in the direction of south-east in winter and north-west in summer; this change of direction seems to be dependent upon the monsoons.

The Behring's Strait Current flows from the Pacific to the Arctic Ocean through the narrow channel which separates Asia from America, and then runs along the northern shores of the latter continent.

The Japanese Current.—This is a branch of the Equatorial Current which flows from the Island of Formosa northward along the islands of Japan, and is finally lost in the ocean.

The Carolinian Monsoon Current is the central part of the Equatorial current near the Caroline Islands. It is influenced by the monsoons running east in winter and west in summer.

16. *The New South Wales alternating Current.*—From the parallel of 28° S. to the south of Van Diemen's Land, this current flows during the summer months (from August to May) as follows:—From the land, to a distance of seven leagues, it sets to the south-west one and one-fourth miles per hour: in the space of 27 leagues distance from the land, it sets towards the north-east at a rate of three-fourths of a mile per hour, and in the winter in an opposite direction. These alternating currents are supposed to depend on the monsoon winds.

17. *Currents of the Indian Ocean.*—Numerous and variable currents are produced by the Equatorial

Current as it rushes through the islands of Asia to the coast of Africa and the Cape of Good Hope. The principal of these are as follow :—

The Bengal Current, which flows along the Coromandel coast, is altogether dependent for its force and direction upon the monsoons. In summer it flows to the north-east, and in winter to the south-west.

The Malabar Current is also dependent upon the monsoons, running southward in summer and northward in winter along the Malabar coast, between Bombay and Cape Comorin.

The United Bengal and Malabar Current.—This sea-stream is formed by the united waters of the above-named currents: from Cape Comorin it proceeds westerly towards the coast of Africa.

The Passage Drift Current.—This is perceptible off the south-west of Australia, from which it flows northerly to about the Tropic of Capricorn. It then runs in a westerly direction towards the coast of Africa. As it approaches the Island of Madagascar it separates into two branches, one of which flows round the north of that island, the second and smaller branch advances towards the Cape of Good Hope.

The Mosambique Current, which is a continuation of the Passage Drift, runs with great velocity between the Island of Madagascar and the mainland of Africa, and thence southward to the southern extremity of the continent. This current is most rapid at Cape Corientes, as its name implies. The mean velocity varies from 18 to 20 miles per day, but this rate is greatly exceeded under particular circumstances. Horsburgh states that the ship "Northampton" was carried 139 miles in 24 hours by this current.

The L'Agullas, or Cape Current, also forms a strong stream, and runs with great velocity between the Cape and the L'Agullas sand-bank.

The Cape Counter-Current.—This is formed by a large portion of the waters of the preceding current, which being resisted by the L'Agullas bank, is returned to the Indian Ocean by a counter-current. It has been observed as far eastward as 65° 15′ E. long.

18. *Currents of the Atlantic Ocean.*—The South Atlantic Current is a continuation of L'Agullas Current. It flows northerly along the African coast to the parallel of St. Helena, whence its course is more easterly till it is turned to the westward by the form of the coast, and the opposition of the Guinea Current from the north; it then changes into—

The Equatorial Current of the Atlantic.—This stretches across the ocean on both sides of the equator till it reaches the central point between Africa and South America: it then divides into two portions, one of which flows along the coast of Brazil, and passes with considerable rapidity round Cape Horn, through the Straits of Magellan into the Pacific. The other branch turns northward and flows through the Caribbean Sea into the Gulf of Mexico. In passing along the coast of Guiana, a portion of it, between the islands of Trinidad and Martinique, receives the name of the *Guiana Current*, and its continuation to the peninsula of Yucatan is called the *Caribbean Current*, then under the name of the *Gulf of Mexico Current* it makes a complete tour of the Mexican Gulf.

19. *The Gulf Stream.*—This celebrated stream issues from the Gulf of Mexico with a velocity of 4 or 5 miles an hour, and flows to the north-east, along the coast of the United States. As it proceeds northwards, it recedes gradually from the shore and diminishes in velocity. On striking the banks of Newfoundland, it turns a little to the south, but still reaches the north-east coast of Europe. This is evinced by the fact that the productions of tropical America are often cast upon the coasts of Scotland and Norway. On reaching a point a little to the west of the Azores, this stream turns to the south and proceeds to the Canaries, again to mingle its waters with the great Equatorial current. Humboldt believes, from the dates of letters contained in bottles, and other objects thrown on shore on the African islands, that the Gulf Stream completes its circuit in a period of from two to three years. Its velocity diminishes gradually from 5 miles to 1½ per hour, and its temperature from 87° to

72°, in its extensive tour of the Atlantic. In its course southward, this stream throws off the two following lateral currents:—

20. *Rennell's Current*, which passes along the northern coast of Spain into the Bay of Biscay, with the velocity of 1 mile per hour. It then turns north along the coast of France, increasing in velocity to 3 miles per hour, and spreading to a breadth of more than 100 miles, until it crosses the mouth of the English Channel, and strikes the southern coast of Ireland.

The North African and Guinea Current begins about lat. 45° N., and flows towards the north of Africa; a portion runs constantly into the Mediterranean Sea through the Straits of Gibraltar, sometimes with such force that ships are compelled to await an easterly wind to sail out against it; the other branch runs close along the western coast of Africa into the Bight of Benin.

21. *The South connecting Current.*—This is produced by the Drift Current of the south-east trade wind, and flows towards the Cape of Good Hope, whence it divides, one branch turning into the Atlantic, and the other passing into the Indian Ocean.

The Arctic Cold Current is formed by two currents, one flowing south-west between Iceland and Greenland, and the other flowing from Hudson's Bay and Davis's Straits towards the east. They unite south of Greenland, and run into the Gulf Stream in lat. 44° N., off the east of Newfoundland. These currents bring down vast fields of ice, which sometimes reach the Gulf Stream, especially in the month of May. They also throw vast quantities of drift-wood on the coasts of Iceland and Greenland, which furnish important supplies of fuel.

22. When two opposing tides meet, they often produce whirlpools; the most remarkable one known is the Maelstrom, on the coast of Norway. In a storm it roars with tremendous noise, and its influence is felt at a distance of 9 miles from its centre. The whirlpool of Charybdis, in the Straits of Messina, was the terror of ancient mariners.—EDWARD HUGHES.

Biography.

LESSON I.

LIFE OF JAMES WATT.

BY HUGO REID.

1. MANKIND do not find everything they want lying around them ready made to their hands, in the state in which they require it for use. Most things need to have some change wrought upon them to adapt them to our wants, and many things have to be brought to us from a great distance, even from the furthest parts of the earth. The soil must be turned up by the plough, the chaff must be separated from the grain, and the corn must be ground. Wool, cotton, and flax, must be spun into thread, and woven into cloth; water and coal

must be raised from considerable depths in the bowels of the earth; and tea, sugar, cotton, silk, indigo, and many other useful articles have to be brought from far-distant places.

2. For all such operations we require *force*, that is, the means of producing *motion*. We must carry, lift, press, turn, or subject to some description of motion, the object which needs a change effected upon it to render it fit for our purposes. In a rude state of society, the only available force is *the muscular power of animals*, either of man himself, or of some of the lower animals, as horses and oxen: in some countries even at this day, the inhabitants have no other means of producing motion; and are, therefore, very imperfectly supplied with those comforts and conveniences which abound among civilized nations. But when the useful arts had made some little progress, ingenious men, observing that water falls with force, and flows with force, and that wind blows with force, contrived *machinery* which they interposed between these natural forces and the objects to be acted upon, and thus arose the various kinds of *water-wheel*, the *windmill*, and the *ship*, spreading its sails to the breeze, instead of being urged on laboriously and slowly by oars. These are very old contrivances—so old, that we have no records whatever of the dates of the inventions, nor of the names of the inventors.

3. About a hundred and fifty years ago a new power came into use, quite different in its nature from any of those previously employed, which has now almost superseded the use of the former sources of motion, and proved far more effective than all of them put together. It is procured by the simple operation of making water boil; and the machine by which it was brought into action was called *the fire-engine*, or *steam-engine*. When water boils, that is, is converted into steam, it occupies about 1696 times the space which it did when in the form of water, and in the act of so expanding, presses with very great force on all the bodies surrounding it, and will burst the vessel which contains it if it be confined; or may be made to impart motion to bodies properly adjusted for the purpose.

Men had long known vaguely that water expands with force when turning into steam. They had seen a small quantity of water formed into a large volume of steam; they had seen the jet of steam which rushes out with force from a boiler; they had seen the lids of boilers violently raised by the force of the confined steam; probably the bursting of boilers when the steam had no outlet was not unknown to them. So long ago as one hundred and thirty years before the commencement of the Christian era, HERO of *Alexandria* gave a description of a sort of toy-machine moved by this force, called the *æolipile;* but it was not proposed to be applied to any useful purpose. Steam-engines on the same plan have recently been made, but they have not been found to work economically. After the revival of arts and letters, DE CANS, BRANCA, the MARQUIS of WORCESTER, DENIS, NAPIER, and others, made suggestions or endeavours to apply the power of steam to useful purposes. THOMAS SAVERY, in the year 1698, took out a patent for a steam-engine which he invented; and several of his fire-engines were actually erected and employed in raising water from mines—the first steam-engines which were applied to do useful work. But they were costly and dangerous. There is a tradition, that at Barcelona, in the year 1542, a Spanish naval officer, BLASCO DE GAVAY, had propelled a vessel without oars or sails by some machinery, of which "a large kettle, filled with boiling water, was a conspicuous part;"—if true, an extraordinary invention at so early a period. But the first steam-engine capable of doing any useful work with safety and economy, was that now called the *atmospheric engine*, or *Newcomen's engine*, invented by NEWCOMEN and CAWLEY, two mechanics of Dartmouth, who took out a patent for it in the year 1705; soon after which it was used in many places to drain the mines, and continued during the greater part of the century to be the machine most in use for the purpose of raising water, whether for the supply of towns, or clearing the mines from the water, which always tended to accumulate, and to impede or prevent the operations of the miners.

4. Towards the middle of the eighteenth century an economical and effective power was urgently wanted. The use of Newcomen's engine was costly, for it was attended with great consumption of fuel. Many of the mines which had been worked for a long period, and to considerable depths, were nearly choked up with water. Towns were growing rapidly, and needed greatly-increased supplies of this necessary of life. A cheap moving-power was required to give effect to the improvements which were made in almost every description of machinery; while the increase of population, the extension of commerce, the growth of superior tastes among the middle and working classes by the diffusion of knowledge, and of the wealth flowing among them from manufactures and trade, created numerous wants, which could be supplied only by greatly-augmented means of producing power or force. At this time James Watt arose, and supplied what society stood so much in need of. He improved the fire-engine so greatly, added to it so many new and admirable contrivances, and extended so immensely its power and applications that he is usually regarded as the inventor of the steam-engine. Strictly speaking, there is no one man entitled to this appellation: it is the joint work of a succession of inventors. But the contributions of James Watt so far exceed those of others, either before or since, not only in the vast benefits which mankind derived from them, but in their number and variety, and in the genius which they display, that he towers above all the others, and his name alone is deemed worthy of being associated with this noble invention.

5. James Watt was born in the town of Greenock in the west of Scotland, on the 19th of January, 1736. His father was a ship chandler in that port; that is, supplied ships with the various instruments, utensils, &c., which they require, and was much respected by his fellow-citizens, among whom he filled the offices of town-councillor and magistrate for several years. Young Watt was of rather delicate health, and hence was unable to attend school regularly; but he evinced a studious disposition; and his father, who was a well-

informed and intelligent man, was able to guide his youthful studies. It has been related that a gentleman one day observing the boy apparently amusing himself with a piece of chalk on the floor, remarked to his father that the boy would be better at school than idling away his time in that way. "See what he is doing before you condemn him," said the father. On examining closely the lines he had drawn, the gentleman found that they formed the mathematical figure for a problem, in the solution of which he was engaged; and on questioning him, he excited surprise by his intelligence, and the extent of his information. It is also said that on one occasion the future inventor of so many great improvements in the steam-engine was reproved by his aunt for wasting his time, trifling with the lid of a kettle, which he was taking off and putting on again, holding cups and spoons over the steam, and earnestly watching the condensation of the vapour into drops of water on the cold surfaces which he opposed to it. The young philosopher had already begun to examine into the phenomena he saw around him; the first step towards ascertaining their causes, and finding out the useful applications of which they are capable.

6. In 1755, James Watt went to London, as assistant to Mr. Morgan, a mathematical and nautical instrument-maker in Finch Lane, Cornhill. In 1757, he returned to Scotland, with the view of establishing himself in Glasgow in a like business. Having some difficulty in settling in a suitable place, on account of the peculiar privileges of the Trades' Corporations, the University extended their protection to him, appointed him their mathematical instrument-maker, and gave him a shop within their precincts. This was of very great advantage to Watt. It enabled him to pursue his business without molestation. It brought him into communication with several very eminent men who were then professors in the university of Glasgow:—JOSEPH BLACK, professor of chemistry, the discoverer of the laws of latent heat; ADAM SMITH, the celebrated author of "The Wealth of Nations;" and THOMAS SIMSON, the well-known editor of the "Euclid" generally

used in this country. And it was by his connection with the university that Watt had his attention particularly turned to the subject of his great inventions and source of his future wealth and fame—the steam-engine.

7. The attention of Watt was first directed to the subject of the steam-engine by Dr. Robison, then a student in the university of Glasgow, afterwards a distinguished writer on mechanical science. Robison projected the application of steam-power to propel carriages on common roads. In 1761 or 1762 Watt himself constructed a simple kind of engine, on the plan of those now called *high-pressure* engines; but soon relinquished the idea of constructing an engine on this principle, from the danger of bursting the boiler, the difficulty of making the joints tight, and other causes. In the winter 1763-4 his attention was again directed to the subject, from having to repair a working-model of Newcomen's engine belonging to the Natural Philosophy class in the University. He was not satisfied with simply repairing the machine and returning it: his inquiring mind sought to satisfy itself as to all the particulars of its action by close examination and by experiments; he soon became aware of the very great consumption of steam (and thence of fuel) in working it; and sought for some means of avoiding or lessening this enormous waste.

8. In Newcomen's engine the motion was produced by the pressure of the air, (hence it was called the *atmospheric* engine,) on a piston at the upper part of a cylinder. The interior of the cylinder was filled with steam; this being condensed into water by a jet of cold water thrown in amongst it, a vacuum was produced, when the air's pressure on the piston being little resisted, forced down the piston. Fresh steam was then admitted below the piston, from a boiler placed under the cylinder, the piston was raised, partly by the force of the steam, partly by a heavy weight attached to the other end of the beam to which the rod of the piston was connected, and the cylinder again filled with steam, which was then condensed as before, and the piston again descended.

But the steam could not be thoroughly condensed, that is, a good vacuum could not be produced, unless a large quantity of cold water were thrown in, by which the cylinder would be very much cooled; and when this was done, a large amount of steam was wasted when it entered the cold cylinder, for the latter condensed the steam into water till it became hot again. We may perceive the same when we hold a cold tumbler over the steam issuing from a boiler; the first portions become condensed into drops of cold water by the cold glass; and it is not till the glass has become warmed by the heat of the condensed steam, that it ceases to turn the steam which enters it into water. Hence arose the great waste of steam in Newcomen's engine at every stroke of the piston; and James Watt saw that this could not be avoided, unless by *some method of making a vacuum without cooling the cylinder.*

9. Now Watt was not only a man of great inventive genius, he had studied and acquired knowledge, without which the highest genius can be of little use. He knew the nature of aërial bodies, such as steam; he knew that they possess an ever-expanding power within them, by which they tend to spread out on all sides, and rush into any empty space to which they have access. Hence, the happy thought occurred to him that, if a communication were opened between the cylinder when full of steam, and an adjoining vessel in which a vacuum was maintained, the steam would rush from the cylinder to that vessel; and if the latter were kept very cool by the constant injection of cold water into it, the steam would be condensed as soon as it entered it, and there would thus be a constant vacuum in it, from which the steam would almost entirely rush into it; *and thus was accomplished the great object of procuring a vacuum in the cylinder without cooling it.*

10. This was Watt's first and great improvement on the steam-engine. It was followed by a number of improvements of great ingenuity, and he converted it from an atmospheric into a real steam-engine, by closing the cylinder at the top, excluding the air

entirely, and introducing steam above the piston to press it down. He made these improvements mostly in 1765, and took out a patent for them in 1769; but he had great difficulty in getting engines on his plan introduced; men are distrustful of new inventions. It was necessary that one or two engines should be erected and be known to have worked successfully; and that there should be a factory where the new engines could be made; all of which required capital, with which Watt was but scantily supplied. After many troubles and disappointments, such as most inventors experience, he entered into partnership, in 1773, with Mr. Boulton, of the Great Soho Works, near Birmingham, a man of capital, influence, and enterprise. Watt settled at Birmingham, where he superintended the construction of his engines. In 1775, Boulton and Watt obtained an Act of Parliament, to confer upon them the exclusive right to manufacture the improved engines for 25 years, which was necessary to protect them from piracy, and secure them adequate remuneration: and this showed the high sense of the importance of Watt's improvements entertained by the great council of the nation.

11. At first, before the mine proprietors had confidence in the reality of the extraordinary improvements effected in the new engine, Boulton and Watt were paid by an allowance of one-third part of the saving effected by the use of their engines. So great was this saving, that on some very large engines erected in Cornwall, the share of Boulton and Watt amounted to 800*l*. yearly.

Had Watt done nothing else than thus improve the engine for raising water he would have been a great benefactor of the human race. But mankind are indebted to him for another great invention, the steam-engine for propelling machinery.

12. The water-wheel and windmill were well adapted in one respect for the propulsion of machinery. They gave at once a circular or rotary motion—that best adapted for application to every description of machine. But Newcomen's and Watt's first engines gave only a rectilineal motion, and that only in one direction; and

so difficult was it considered in those days to procure a regular circular movement directly from these engines, that it was proposed by engineers of ability to apply their power to raise water in the usual way, and then cause that water to fall upon a water-wheel, by which the circular motion would be obtained. But the genius of Watt soon devised means of applying the new power to produce the circular movement. He made the steam press the piston up as well as down by ingenious arrangements of the valves; and by a number of the most beautiful contrivances, which seemed to rush into his mind just as they were required, he adapted the boiler and engine to yield from the alternate rectilineal movement of the piston a steady, uniform, circular motion. For this, called the double-acting engine, Watt took out a patent in 1782, and since that time this engine has been the chief moving-power employed for impelling machinery, and it has not been necessary to confine manufactories to those localities where water-power could be had, nor have they been dependent on the weather for supplies of water, or of the still more precarious element—wind. Useful labour is not now brought to a stand because the streams are dried up, or the wind ceases to blow; but at all places, times, and seasons, wherever fuel can be had and a little water—for these are the food of the steam-engine—there this great power may be set to labour for the good of mankind. It is now in action in every quarter of the world, doing the world's work, raising water and mineral treasures from the bowels of the earth, carrying from place to place, on land or over the waters, ploughing, reaping, grinding, hammering, turning, boring, printing, and assisting in every factory; serving mankind night and day all the year round, and doing for them what would require the force of millions of horses, and much of which could not be done at all without its powerful aid. No invention, except that of printing, has done so much for the progress of civilization and the useful arts.

13. We cannot have any adequate conception of the wonderful fertility of inventive genius displayed by

Watt, unless we are able to contrast the imperfect form and limited powers of the rude machine upon which he had to work, with the highly-finished state and varied powers of the engine which he produced. Not only did he render it infinitely more powerful and economical in its action, and capable of application to an infinite variety of purposes, but, by a number of contrivances of very great ingenuity, he made it *self-regulating*, so that, when once set in action, it adjusted its rate of movement to the work to be done, and the consumption of fuel to the rate of movement required. With but little change it was afterwards adapted to the propulsion of ships; and steam navigation is now established between the most distant places on the earth's surface. This very important application was first successfully made in the United States of America in 1807, and in this country in 1812; both of which Watt happily lived to witness.

14. In 1800, when the patent granted him by Parliament expired, Watt retired from business; but he survived till 1819, when he died at his seat, Heathfield, near Birmingham, at the advanced age of eighty-three years. Men then felt that a master-spirit, one of the greatest benefactors of the human race, had passed away. Shortly after his death, public meetings were held in the leading towns of the kingdom, which were attended by the most distinguished men of each district, who united in the warmest eulogiums on the genius and character of Watt, and on the inestimable benefits he had conferred on mankind. Subscriptions were entered into, and monuments erected to his memory in Westminster Abbey, and many other places throughout the country. In 1814, he had had the high honour conferred upon him of being chosen one of the eight foreign associates, of the most illustrious scientific body in the world—the National Institute of France; and some years after his death, an Eloge, comprising a memoir of his life, was read before this body by the distinguished French philosopher, Arago, which has been translated and published in this country.

15. James Watt was not a mere mechanician. He

was a man of great general information, and of a highly-cultivated mind. "His talents and fancy," says his celebrated countryman Sir Walter Scott, "overflowed on every subject. One gentleman was a deep philologist,—he talked with him on the origin of the alphabet, as if he had been coeval with Cadmus; another a celebrated critic,—you would have said that the old man had studied political economy and belles-lettres all his life;—of science, it is unnecessary to speak, it was his own distinguished walk. And yet when he spoke with your countryman, you would have supposed he had been coeval with Clavers and Burley,—with the persecutors and persecuted; and could number every shot that the dragoons had fired at the fugitive Covenanters." From his boyhood upwards, Watt possessed a rich fund of anecdote, and was in the habit of entertaining his friends with tales—improvised romances—which he composed as he went along, containing the usual incidents, adventures, escapes, descriptions of costume, character, and scenery, found in such compositions. This practice, begun in his early youth, he continued to a late period of life.

16. James Watt was twice married, and had two sons, one of whom survived him. The other, Mr. Gregory Watt, had given early promise of scientific eminence, but died while still a youth. The name of Watt, however, will live in the memories of men, so long as they continue to honour the successful application of genius to benefit the human race. While the steam-engine remains the chief means of furnishing moving-power, the man who first rendered it thoroughly efficient must be held in remembrance: and should it ever be displaced by some new source of power, men will not readily forget the great deeds it has done during the present century, nor the name of him whose inventive genius armed it with these extraordinary powers.—Hugo Reid.

Geology.

LESSON I.

THE ART OF MINING.

BY WARINGTON SMYTH.

"As for the earth out of it cometh bread: and under it is turned up as it were fire" . . . "The stones of it are the place of sapphires: and it hath dust of gold."

1. **General Character of Mineral Deposits.**—The minerals which it is the object of the miner to search for and extract are, for the most part, met with in one of two kinds of deposits, in *beds* or in *veins;* the former accumulated during the formation of the rocks with which they are associated, the latter introduced at some later period.

The *beds*, *strata*, *seams*, or *sills*, as they are locally termed, are characterized by lying parallel to the stratified sheets of rock, clay, &c., which spread above and below them; and having been subjected with them to the same movements of elevation, depression, contortion, and dislocation, offer greater or less difficulty to the operations of the miner according to the prevalence of these disturbances. The value, therefore, of a deposit of this kind must depend in part on its freedom from such accidents, as well as on its constituent substances and thickness. Sometimes the entire stratum is formed of the workable material, as, for example, certain beds of coal; whilst more frequently a portion only can be extracted to advantage, and the remainder is regarded as refuse, this being commonly the case in the numerous beds of iron ore which form so important an element in the mining industry of Great Britain.

2. If of great intrinsic value, or favoured by local circumstances, beds may be worked, when their thickness is very small, as the copper-bearing slate of Mansfeldt in Prussian Saxony, which is in some places no more than six inches thick; and certain seams of coal worked in the hilly districts of Northern England are so thin, that the excavations opened by the colliers are not more than twenty inches in height.

On the other hand, beds, even when composed chiefly of one kind of mineral, sometimes attain very great dimensions, as do the strata of rock-salt, which are often above thirty feet in thickness, the Dudley seam of coal, amounting occasionally to nearly forty feet, and some beds of lignite, or brown coal, to as much as sixty feet, rendering it necessary to employ peculiar methods of mining to extract them with safety.

3. A particular variety of these stratified deposits is formed by the beds of clay and gravel which have been carried down from higher grounds by the action of streams of water, and contain grains and lumps of tin ore, iron ores, platinum, and gold, broken and washed away from their original position.

These constitute what are called the *stream works* in Cornwall, which have been explored for tin from the earliest ages, and the alluvial layers or "diggings" which have, of late years, been so productive of gold in Siberia, California, and Australia.

4. *Veins* or *lodes* are the principal sources of the ores which produce silver, copper, lead, tin, and the numerous other metals more or less important in the arts and manufactures. Imagine a crack or fissure running through the crust of the earth from the surface downwards to an unknown depth, extending in a nearly straight line for a few hundred yards or for several miles in length, and of a width which varies in different cases from an inch to above one hundred feet; then suppose this crack to be filled with a mixture of minerals and fragments of the rock which it intersects, and you have the general character of a lode or mineral vein. Of the minerals which compose its substance, some, of the description called spars, contain no useful metal, as quartz, calc-spar, heavy-spar, fluor, &c.; and when these preponderate, the lode is said to be poor. The metalliferous minerals are, for the most part, combinations of the metals with oxygen, or with sulphur, or arsenic: more rarely the metals are found in their native state, or forming salts by the union of their oxides with acids. Thus the most important ores of copper in Great Britain are the oxides

called from their colours "red" and "black copper ore," the sulphide, "gray ore" or "copper glance," and the gold-yellow mineral "copper pyrites," composed of sulphide of copper and sulphide of iron. Occasionally the metal is found in its pure state, as "native" or "malleable" copper; and as a carbonate in the form of the beautiful green mineral termed malachite.

Lead is principally obtained from galena, the natural combination of lead and sulphur; and tin solely from "tinstone," the combination of tin with oxygen.

There are some veins, particularly those of smaller size, termed "strings" and "branches," which have been filled entirely, or nearly so, with one kind of mineral, as, for example, strings of tinstone in granite, of asbestos in greenstone rocks, of calc-spar in limestone, &c.; but those which offer inducements to mining enterprise are generally more complicated in their structure.

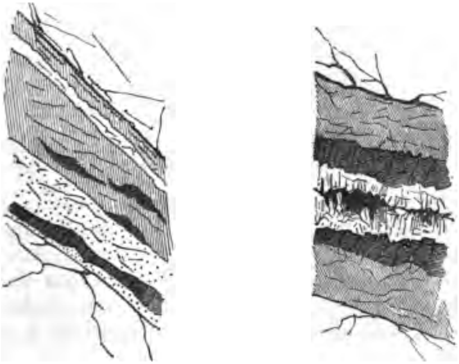


Fig. 1. Fig. 2.

Sections of Lodes, from Lead Mines in Wales.

Fig. 1, a ribbed lode, in which the darkest shade represents lead ore, and the dotted part iron pyrites.

Fig. 2, a lode in which the constituent minerals, zinc-blende, galena, and quartz are regularly repeated on each side, from the "wall" toward the centre.

5. In a great proportion of lodes, the various minerals which they contain are distributed without any

definite order, but in others we may trace a regular arrangement, which proves, beyond a doubt, that different substances have been deposited in succession against the sides or " walls " of the fissure. It is thus evident that one group has had time to solidify, and to assume the crystalline figures proper to its constituent minerals, before a second and a third group have been in like manner deposited over them.

Not only can we hence infer that the formation of such lodes has occupied long periods of time, but we can also indicate which are the older, and which the newer minerals, as regards the time of their introduction into the once open space.

6. Another kind of structure, which may be termed fragmentary or brecciated, may often be observed in lodes, and proves that the rock forming the sides of the original fissure has been broken into small fragments, and then cemented together by some newly-introduced mineral. Occasionally it may be shown that the lode itself has thus been anew cracked open or broken into fragments, and afterwards reagglutinated in a similar manner.

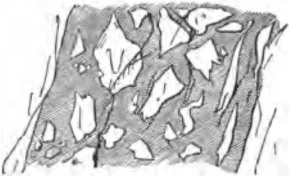


Fig. 3.

Section of a brecciated lode; the light parts representing fragments of the "country" or adjoining rock, the dark part ore.

In many instances this reopening of a vein, in consequence of subterranean movements of elevation, has taken place along one of its walls or sides, without breaking up the minerals which had previously been aggregated. The new fissure thus formed has been filled up sometimes by an additional vein of a similar character, and at others by a different class of substances.

7. It rarely happens that a single lode is found coursing by itself through a country; most commonly it is accompanied by a number of others, more or less parallel in direction and similar in composition.

In the majority of mining districts, as in Cornwall, Saxony, the Hartz mountains, &c., an assemblage of mineral veins running thus parallel is crossed by a series of others running in some opposite direction, termed from this circumstance "cross-courses." The two directions are marked by the fact of their veins carrying a different kind of material. Thus in Cornwall, whilst the lodes which run east and west produce tin and copper ores, those which course from north to south contains either lead or iron ores, or simply quartz or clay.

The latter of these, where they meet the former, cut completely through them, and often shift or dislocate the portion on one side to a distance from that on the other, proving that the "cross-courses" were formed after the completion of the other lodes, and that their formation, was accompanied by movements of the adjacent masses of rock precisely similar to those of which such good evidence is afforded to geologists and coal-miners by "faults," in the stratified rocks.

8. From the nature of the ores which are found in lodes, so subject to be altered by the action of air and water, it is not to be expected that they should present such an appearance at the surface of the ground as to lead unpractised persons to an appreciation of their value. The top or "back" of the lode has, by these agencies, generally been changed into a brownish, ochry substance, termed by the miners "gossan," which consists in great part of oxide of iron; and although often exhibiting no trace of more valuable ore, it is an object of great attention, as presenting to the experienced eye an indication of what may be expected in the depths below.

It was the favourable appearance of a "gossan" which led to fresh researches, after some previous adventurers had abandoned it as useless, at the mine called the Devon Great Consols, on the banks of the Tamar. At the additional depth of a few fathoms the lode rapidly became productive of an enormous quantity of copper ore; and the mine is now, after ten years of amazing success, valued at no less a sum than 440,000*l.*

9. In consequence of these peculiarities, the search after lodes in untried ground often becomes very laborious. Sometimes, it is true, they may be tracked out by following to their source fragments of ore or vein-stone called "shoadstones," stragglers from the main body, which have been carried down the course of streams or lie scattered over the surface.

But it is often necessary to dig a series of trenches in a direction across the usual "run" of the lodes, deep enough to explore the surface of the solid rock, the "shelf," which is then examined carefully for any appearance of veins. If the alluvial cover be deep, small pits, "costeaning pits," are sunk at convenient intervals, and the intervening spaces explored by galleries driven close upon the surface of the "fast" or solid rock.

In districts of different character, the "back" of a lode may be exposed in a brook-course, or a deeply-cut roadway, or in the face of a cliff. Sometimes, if harder than the adjacent rock, it will project, like a wall, from the surface of the ground; whilst in other cases it may be revealed by the operations of the plough, in the cutting of a drain, or by other accidents.

10. Experience has shown that productive lodes are most frequently found near the junction of two different kinds of rock, as granite and clay slate, the "killas" of miners; and again, that particular varieties of stone are more favourable than others to the richness of a vein at those places where it intersects them. These and an infinite number of other indications only become well known to that class of miners who have watched with care and thoughtfulness the effect of the constantly-varying appearances which are presented to them in the working of mineral veins.

11. Tools for breaking ground.—According to the hardness and structure of the material to be excavated, the miner has to employ a variety of implements.

If the ground be moderately soft or "easy," as gravel, or chalk, a sharp-pointed shovel and a pick are sufficient for the purpose, the latter being generally made with one end pointed and the other flattened into a short hammer. In rock of somewhat harder character, wedges of steel, or of iron tipped with steel, are driven into the natural joints by repeated blows from a heavy hammer, and this was till within one hundred and fifty years ago the only method of penetrating the most obdurate stone. Coal is wrought by first cutting out with a pick deep grooves in such a manner as to disengage a mass of the substance on two or three sides, and then by means of wedges placed in a row and forced in by successive blows, breaking down the entire mass thus prepared for "falling."

12. The force of gunpowder was not used in mining for centuries after its introduction into war, but at the present day is most extensively employed upon rocks of nearly every description. The process is a very simple one: a hole is bored in the stone, like the barrel of a gun: a charge of powder is placed at the bottom, then covered up to the muzzle by clay or other material rammed in as "tamping," and exploded by means of a fuze or train extending from the outside to the midst of the charge. The direction and depth of the hole, as well as the quantity of gunpowder are, of course, so regulated that instead of the tamping or wad being shot out, as from a gun, the rock which forms the sides is shattered or burst asunder.

13. The boring is effected by means of a bar of iron, the "borer," armed with a chisel end of steel, which is kept continually turning in the hole whilst it is struck on the head by a heavy hammer. In some districts it is usual for one man to perform the whole operation, turning the borer with his left hand, and striking with his right, or *vice versâ;* whilst in other places one man is occupied solely in turning the borer, another or sometimes two in striking. The latter method renders it convenient to use larger borers, and to make the holes 20 or 24 inches deep, whilst by the former 14 or 16 are seldom exceeded. The "bit," or cutting part of the

borer, may in some kinds of stone remain uninjured for days or even months together, whilst in certain granites and siliceous veinstones it may destroy the edge of 50 borers in succession to make a hole a foot deep.

14. The practice of blasting was always attended with danger, till the introduction of the safety-fuze, by which fire is communicated to the gunpowder in such a manner as to obviate most of the sources of accident. This simple and economical contrivance, the invention of Messrs. Bickford and Smith in Cornwall, consists of a train of powder protected by an envelope of cord, which lies in the hole during the process of tamping, and is cut to such a length as to allow the miners abundant time to retire. In almost all circumstances it should be employed where due regard is paid to the value of human life.

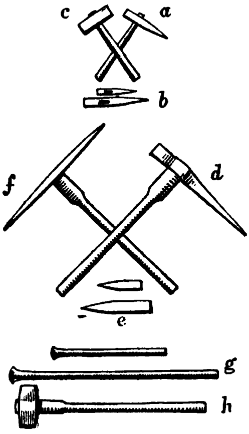


Fig. 4.

Fig. 4 represents the tools above described : *a*, is the ancient miner's wedge or "iron," still used in the continental mines; *b*, wedges of different sizes, to be fixed temporarily on the same handle; *c*, the hammer for driving them; *d*, is the Cornish pick; *e*, the wedges or "gads, to be driven by the last;" *f*, collier's pick; *g*, *h*, borers and hammer employed for two-handed boring.

LESSON II.

WORKING OF MINES.

"A land whose stones are iron, and out of whose hills thou mayest dig brass."

1. **Preliminary Excavations, Shafts and Levels.**—A mineral deposit must in the first instance be opened by means of preparatory workings, the arrangement of which will depend on the character and

position of the bed or the lode. The more or less perpendicular openings, like large wells, are termed *shafts*, whilst the horizontal galleries are called *levels* or *drifts*, and when they open to the surface in some valley, or on a hill side, *adits*.

Where the latter mode can be brought into action, it is advantageous as affording an outlet to the subterranean waters, and particularly so when the situation admits of the level being driven in the actual thickness of the deposit which is to be worked. If the gallery should have to be excavated through barren rock before it arrive at the object of search it is termed a *cross-cut*.

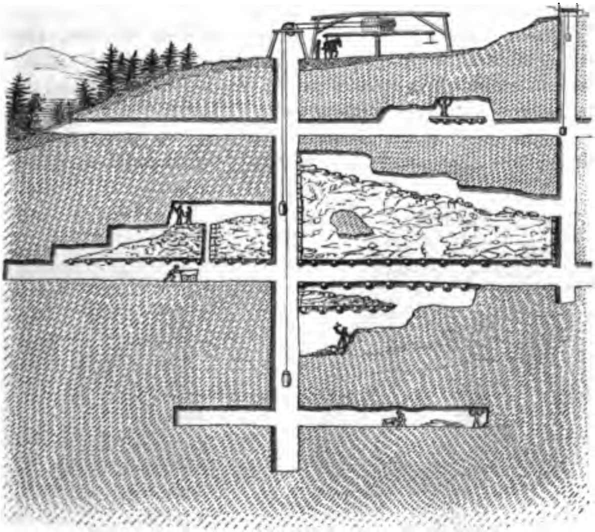


Fig. 5.

These levels in well-managed metalliferous mines are about 7 feet high by 4 or 5 feet wide, but in stratified deposits must depend for their dimensions in great part on the thickness of the bed.

2. Where a seam of coal or other bed is to be worked by shafts, they are of course sunk perpendicularly to the required spot; but where a lode is to be explored,

it is often advisable to sink the shaft in the vein itself, following its inclination downwards, and proving its character step by step.

As it advances in depth, galleries are driven out in each direction on the course of the lode, and at intervals below one another, generally of 10 fathoms or 60 feet. A vertical section, which supposes the rock to be entirely removed from one side of the lode, so that we can see it in its full length and depth, will exhibit these particulars more clearly than any description.

In the little mine here represented, there are two shafts, in one of which the ore is drawn out by a windlass, in the other by a horse-whim.

Three levels or galleries have been driven, the uppermost of which, opening into a valley, is the adit, whilst the two lower ones are at the depths of 10 and 20 fathoms respectively below the adit level.

3. So long as the shafts and levels are excavated in firm rock, they may be left without any artificial support, but when the ground is soft, or much jointed, or liable to decompositions, it becomes necessary by various means to secure the roof and sides against falling in. These precautions must often, particularly where underground water is abundant, be undertaken on a very large scale, and form a serious item in the current expenses of a mine. Wood is the material of most frequent application, and large forests are every year

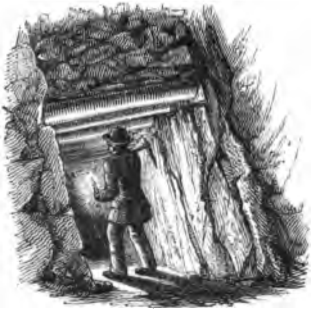


Fig. 6.

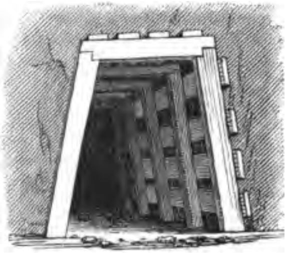


Fig. 7.

thus buried in the depths of the earth, whether they are cut, as in most mining districts, from the woods of the neighbouring hills, or are transported, as into Cornwall, hundreds of miles across the seas from the pine-clad heights of Norway.

4. The mode in which timbering is applied depends on the direction of the pressure of the ground, whether it comes from above only, or from the sides as well. Three of the most common forms are exhibited in the subjoined figures. Fig. 6 shows how single pieces of timber, "stemples," are placed across from wall to wall to support a weight above them. Fig. 7 represents the mode of resisting a pressure from three sides, by means of two stanchions or "wall-plates," and a "cap" fitted upon them, each side being lined where it is required by planks or "laths" to prevent the falling of small portions of the rock; while fig. 8 represents the mode of supporting the roof, when one side is weak and the other solid and firm.

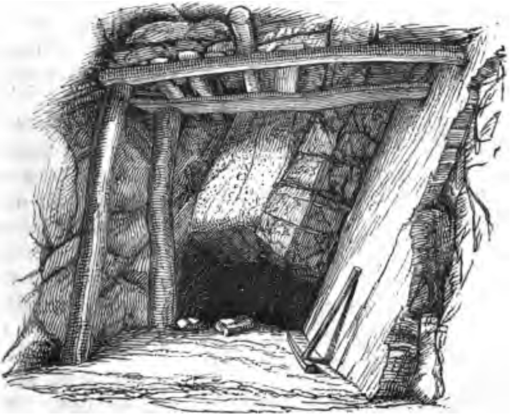


Fig. 8.

5. The securing of shafts, particularly when of large dimensions, is an operation of greater difficulty. In metal mines the shafts are rectangular, and divided generally into two portions by a "casing" or "brattice" of

woodwork, which separates the part where the buckets for raising the minerals pass up and down, from that in which the pumps are placed, and where the men ascend and descend. Several different modes of arranging and jointing the frames of timber are in vogue, but, with all of them, the same principles must be observed, viz., that the wood be so fixed as to oppose in direction the chief pressure or thrust, that the frames be closer together according to the weakness of the ground, even to the extent of being laid in close contact one upon another, and that at intervals the weight of the timbering be supported from below by stout balks or stems termed "bearers," the extremities of which project one or two feet into the firm rock, so as to secure a safe foundation.

Stone and brick are also largely employed for the security of subterranean works. Galleries are protected by arches, either above or all round, according to the character of the pressure which they have to sustain. The shafts or pits of collieries in Britain are generally lined with brick, except where they pass through hard ground; and, with a view to their strength, receive a round or an oval form, with a diameter of from six to sixteen feet. Such a structure, if placed on the surface of the ground, would resemble a lofty tower, often much higher than our tallest church-spires; indeed, if we were to compare some of the deeper shafts with well-known edifices, we should find the latter sink into insignificance, for the pits of some of our great mines would

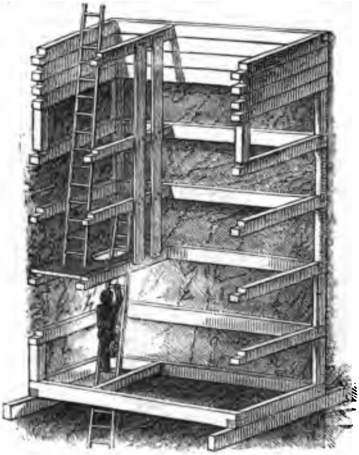


Fig. 9.

exceed the height of four St. Paul's Cathedrals, piled one on the top of the other.

6. It often happens that the sinking of a shaft is incommoded by heavy springs of water, which it would be very expensive to have to pump from the bottom of the mine. It is, therefore, important, where it is possible, to dam them back, so as to prevent their pouring into the open space. This may be so successfully accomplished, that not a drop of water shall leak in, although the feeders or springs may have supplied above a thousand gallons a minute. The mode of effecting it, called "tubbing," is to choose a bed of firm rock, below the watery part, and from that foundation to build the sides of a kind of tub, as large as the shaft, which, instead of holding water inside it, shall keep it out. This is built up to some place above the watery portion of the ground, at which it can be securely connected again with water-tight rock, and thus the subterranean streams, being unable to penetrate, are obliged to take their course elsewhere.

The tubbing may be constructed either of wood or iron. In Belgium the former material is generally employed, and placed in a polygonal form: in England cast-iron is found to be less expensive, and is fitted in segmental portions, accurately cast to fit the circle. Whatever the material, a principal object of care is the filling of all the joints with wedges, first of soft and then of hard wood, driven in as long as a chisel can make room for them, and amounting sometimes to several thousand in the space of a few square feet.

7. WORKING AWAY OF THE MINERALS, OR EXPLOITATION.—When a sufficient portion of the mine has been opened out in the manner above described, the next operation is to extract the minerals of a deposit in a manner more economical than can be effected in the narrow openings of shafts and levels. In most lodes the valuable material is so unequally distributed that many portions have to be left untouched, and other parts may be profitable or not, according to the temporary price of the metal. In nearly all cases a large portion of the broken vein must be left underground as rubbish,

" deads," or " attle," and serves the useful purpose of filling up the excavations, and forming a support to the natural walls.

8. A lode may be attacked from any gallery downwards by "underhand stopeing." The ground is divided into a series of steps, on each of which a set of men may be employed, without interfering with others, and having one always in advance of the other. As the work proceeds in depth, timbers are stretched from wall to wall, and covered with planks, on which are piled the heaps of "attle." But as this method entails several disadvantages, it is generally replaced by the mode of working upwards from below, or "overhand stopeing." The roof of a level is broken away upwards, and when the excavation is sufficiently high, a timber platform or "stull" is put in, upon which the men may stand to proceed with their work. The ground is similarly divided into steps, each one regularly in advance of the next, and the broken vein-stuff, or attle, forms, as the men ascend, a continually-increasing heap, upon which they can stand to attack the roof above them; or they may erect temporary stages to serve the same purpose.

Fig. 5 exhibits both these methods in progress in a mine of small extent, the *underhand stopeing* being seen below the 10-fathom level on the right-hand side.

9. It is a far more serious task to determine the arrangement which is most suitable for the working of a bed of coal. In this case the great variety of conditions, under which it may occur, renders it necessary to choose from among a great number of different plans of exploitation. The thickness of the bed, its quality and angle of inclination, as also the character of the strata immediately above and below it, technically called the "roof" and the " floor," must all be taken into account; and since a large district has often to be excavated from one starting point, it is needful for the manager or "viewer" to be far-seeing enough to calculate on having always a sufficient quantity of ground open to supply the required produce, and yet so to regulate the excavations that no part shall be injured by the exhaustion and abandonment of another.

Additional importance is lent to this subject by the fact, that the ventilation, upon which the lives of all the workmen depend, must be regulated by the plan which is adopted for the extraction of the coal.

10. To avoid entering too much on detail, we may consider that the numerous methods of working coal are divisible into two heads:—1st, that in which solid blocks or "pillars" of coal are left, as the excavations proceed, to support the overlying strata; and 2nd, that by which the entire bed is worked continuously away. Each of these we may examine separately.

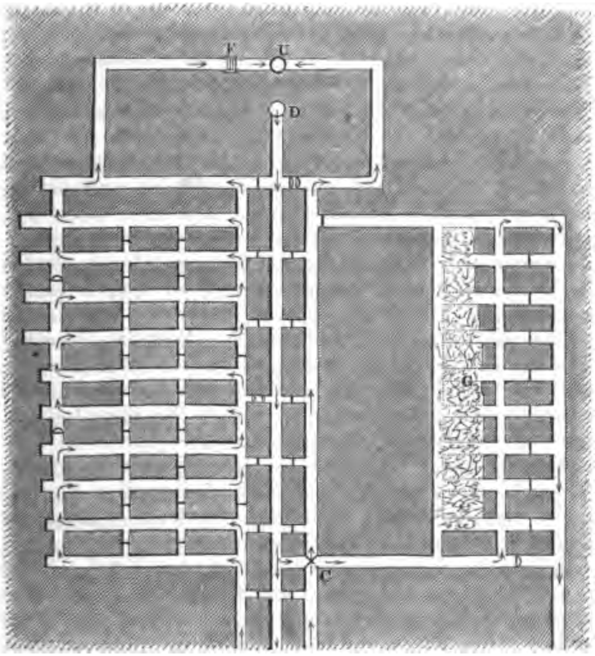


Fig. 10.

The first mode of working, by "bord and pillar," or "post and stall," is extensively used in the north of England, and may be easily understood by aid of a plan or map which represents by a black shade that portion of the coal which remains unwrought. The excavations of a single colliery are sometimes carried on over so large a space, that it resembles a good-sized town with an infinite number of streets and lanes laid out with great regularity; we must, therefore, for convenience, only include in our plan a small part of such workings, or consider it to be only in its commencement.

11. When the seam has been reached by the shafts U, D, and one or more principal roadways or levels have been carried to a sufficient distance from the shafts, "bords" are driven out at regular intervals in the coal. These are chambers of from 10 to 15 feet in width, which, when they have extended to a certain length, are brought into communication by cross passages termed "thirls." The rectangular "pillars" or pieces of coal thus shaped out, have been, where economy was not properly studied, intended solely for the support of the roof, and therefore left as small as was consistent with safety at the moment. In other cases they have been left only a little larger with a view to afterwards "robbing," or partially removing them. But ere long, under such circumstances, the pressure from above either crushes this solid coal so as to render it useless, or forces the softer floor to "creep" or heave up into the excavations, till, in many instances, a loss of more than half the entire coal has been sustained, an evil of the most serious nature when we regard the high importance of cheap coal to the community.

Of late years, especially in Durham and Northumberland, where coal-mining is conducted on a gigantic scale, the pillars have been formed of such dimensions (for example, 90 feet long by 60 feet wide) that they remain uninjured by the pressure: then after the coal has been "won" by extending the labyrinth of passages over a considerable district, the colliers begin to attack the pillars farthest from the shaft, remove as much of them as possible, and with the falling roof continually following them, work their way back towards the shafts.

A more modern practice is to open out only a small district of pillars at a time, and to clear them away at once, as shown on the right-hand side of fig. 10, in the part marked G.

12. It is often with considerable risk that these latter operations are carried out, and a constant source of danger frequently exists in the "goaf" or "gob," the space from which the coal was extracted, now more or less filled with a confused mass of broken stone, but sufficiently open to act as a magazine for the fire-damp which oozes out from the coal or some of the adjacent beds. The goaf is represented at G, figs. 10 and 11.

The difficulties of excavating a bed or stratum by this method increase very much with the thickness of the deposit. Hence, in working the "thick coal" of Staffordshire, a seam averaging 30 feet of material which is removed in one excavation, the usual method is to limit the part operated on at one time to a parallelogram of small dimensions, the roof of which is upheld by several stout pillars of 8 or 10 yards square. These lofty chambers have somewhat the aspect of a blackened Egyptian rock-temple, and their funereal hue is but too suggestive of the numerous fatal accidents which occur, when large masses of the upper part of the seam suddenly fall without warning. A solid wall of coal is left surrounding the "side of work," pierced only by a single opening, which, as soon as the available coal has been extracted, is blocked up by a dam, for the purpose of excluding the atmospheric air, which would tend to excite spontaneous combustion in the small coal and refuse.

13. The second mode of working to which I have adverted above, and which is termed the "long wall," fig. 11, consists in removing the whole of the coal in a more or less continuous face, allowing the roof regularly to fall close behind the men as the work advances. This method may be conducted either by driving roadways in the coal to the limits of the field, and then cutting it away towards the shaft, or it may be commenced from the neighbourhood of the shaft outwards, in which case the roadways have to be maintained, often

with great difficulty, through the goaf or gob, the tract from which the coal has been removed.

To effect this with safety, pack-walls are built up on each side with the stone brought down by the falling upper strata, and as soon as the roof is pressed down, or the floor forced up into the roads, the protruding part is cut away so as to leave open a passage of sufficient dimensions for the transit of the waggons in which the fossil fuel is conveyed to the shaft.

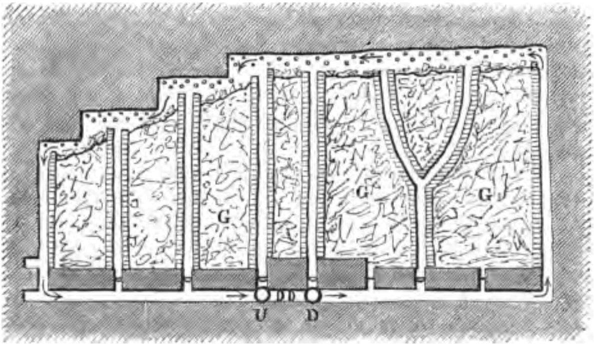


Fig. 11.

14. The actual "getting" of the coal, upon this system, is a beautiful spectacle, often depending much for its success on the peculiar planes of cleavage which traverse the bed, and on the enormous weight of the overlying strata being brought to bear at the right time. The first operation is to cut a notch, to the

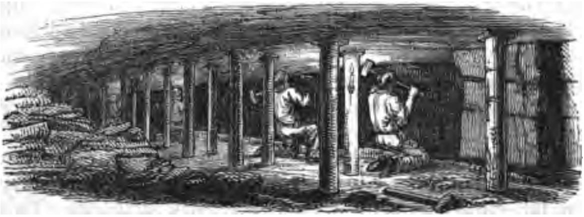


Fig. 12.

depth of about a yard, in the bottom of the seam, along the whole length of the "face" of coal; and then similarly deep notches may be cut vertically, so as to subdivide this length into convenient portions. When the "holing" and "shearing" have thus been effected, the "falling" is commenced. The colliers, working protected against the fall of the roof by a double row of wooden props, which are to be removed forward as the work advances, plant a number of wedges along the top of the seam, and with heavy sledge hammers open a battery of blows along the entire line. After a time the entire wall begins to rend and crack, and at last down comes the mass, often in long blocks of several tons in weight, and detached as far as the notch or holing had extended.

The tendency of the roof is now, of course, to fall nearer to the face of work: the props are therefore drawn (very little of the wood being actually lost), and set up nearer to the fresh wall of coal, and the next day the same process is repeated.

When beds of some other kind of material, as limestone, rock-salt, or iron-stone, are to be extracted by mining, methods are adopted so similar to what has been sketched out under the two above heads as to need no farther description.

LESSON III.

VENTILATION.

"At the hand of every man's brother will I require the life of man."

1. THE ventilation of mines demands great and constant attention, because the air, if allowed to stagnate, soon becomes so vitiated as to be unfit for breathing. Moreover, a large proportion of the coal seams give off a gas called carburetted hydrogen, which, when mingled with several times its volume of air, explodes violently if brought in contact with flame. It is this dreaded "fire-damp," often termed "sulphur" by the colliers, which in our own and the Belgian collieries has so often occasioned a fearful slaughter, and which,

in spite of all that has hitherto been done to disarm it, claims its hundreds of victims every year.

The effects of such explosions are very various, according to the quantity of the gas which takes fire, and the proportion in which it is mixed with air. It may merely singe those men who are in the immediate neighbourhood, or it may, with a force like that of gunpowder, dash their mutilated bodies into one common ruin, with horses, waggons, and all that it meets on its destructive path.

2. Two methods have been devised to avoid these calamities; the one is to furnish the men with *safety-lamps*, by means of which the access of flame to the fire-damp is prevented; the other is to introduce into the workings such a quantity of air as may dilute or render harmless, and continually sweep away all the gas which oozes out of the coal or rock.

This latter is, in effect, ventilation, which, when scientifically planned, thoroughly carried out, and combined in certain situations with the use of safety-lamps, offers every reasonable safeguard.

3. Of the safety-lamp it need only be said, that it was first proposed by the great chemist Sir Humphry Davy, at a time when the attention of all thinking men had been called to the subject by the sudden destruction of 92 men and boys in the Felling Colliery. The lamp, as suggested by him, simply had its flame enclosed within a cylinder of wire-gauze, and on being carried into an explosive atmosphere, was at once found to be successful. Yet the dulness of its light has been made a great objection to its use, and many a poor fellow has fallen a sacrifice to the thoughtlessness or foolhardihood of some collier who, for the sake of more light, has exposed a naked flame to the attack of the unseen enemy. A great number of modifications of the Davy have been proposed, but their effectiveness must depend, in a great measure, on the care and caution with which they are used in dangerous places.

4. Let us now consider the principles on which a current of air may be made to pass through underground excavations. The reader only requires to be reminded,

1st, that warm air is specifically lighter than cold air; and 2ndly, that the interior of the earth, even at a small depth, preserves a uniform temperature throughout the year, whilst the air on the surface is affected by the change of the seasons.

If we take the common instance of a mine communicating with the open air by two shafts, one of which is at a higher level than the other, and compare the columns of air contained in them, and continued up to the limits of the atmosphere, we shall see that the two columns can seldom be so nearly of the same weight as to balance one another. In winter, the air in the mine A B, and in the shafts will be warmer than the external air; A C will be lighter than the column B E of corresponding height, and will therefore tend to rise, or in other words to be pushed upward by the heavier column B E; and as the cold air of this latter will in its turn be warmed, on passing into the mine, a continuous current will be established.

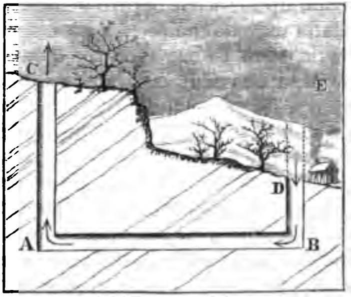


Fig. 13.—Winter.

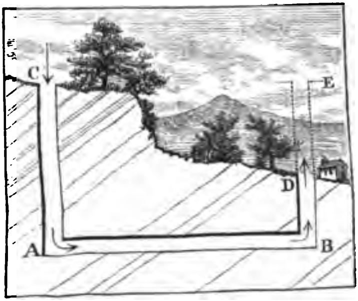


Fig. 14.—Summer.

But in the summer, if the workings are shallow enough to be cooler than the outer air, the action must be reversed, for A C would then be heavier than E B, and the current would pass in the contrary direction, as represented by the arrows.

5. Thus what is termed "natural ventilation" is set up, a process which is sufficient in some cases, particularly in most metallic mines, where there are several openings to the daylight at different levels, where no very great amount of air is required, and where no danger is incurred when the current changes its direction.

But when the shafts are nearly at the same level, as in a great majority of collieries, artificial means must make up for what nature denies. The top of one of the shafts may be encircled with a tower or "stack" of brick-work, so as to lengthen the column of underground air; or a mechanical contrivance, as a fan or screw, or air-pump, may be employed to induce a current; or lastly (which is the most usual method) the air in one of the shafts may be heated by a fire, so as to destroy the equilibrium between the two columns, and to establish a moving power, proportional to the difference of temperature between the incoming and outgoing, or, as it is termed, the downcast and upcast air. U and C, figs. 10 and 11, indicate the upcast and downcast shafts.

To this end, in small works, a "lamp" or grate full of burning coal is suspended by a chain in the upcast shaft; whilst in the large collieries, huge furnaces are constructed near the bottom of the pit, which are fed day and night by men, whose sole duty is to attend to the action of this heart of the circulation of the mine. F, in fig. 10, shows the position of the ventilating furnace.

6. Of late years much attention has been bestowed on the practicability of supplanting the furnace by a jet of steam acting in the same manner as in the funnel of a locomotive; but theory and experiment have both shown that the latter, although sometimes valuable as an adjunct, would be a more expensive and inconvenient method of accomplishing the same end. Moreover, it must not be forgotten that the generation of a current of air down one shaft and up another is a very small part of the task required. The most important and difficult portion is to distribute the air in such a manner through all the complicated recesses of a mine, that no chamber shall remain stagnant, and no workman be

left without a sufficient supply to render his working-place wholesome and safe.

7. The first step towards this object, is, of course, to divide the ingoing from the outcoming air or "returns," by putting in dams termed "stoppings," wherever the two streams would communicate short of the extremity of the workings, or by fixing air-tight doors, wherever it may be requisite to open occasional means of passage for the men or the waggons of coal. One current has sometimes to cross the direction of another, and is then guided either under or over by a separate passage termed a crossing (C, fig. 10). These arrangements will be seen by reference to fig. 10, where the stoppings are represented by strong black lines, filling up all the communications which it was necessary to form during the earlier progress of the works. The arrows in the diagram represent the course of the *ventilating* currents. By such obstructions the air is guided through the whole of the *bords*, up one set and down another, so that no part of the workings shall be left "dead" or stagnant. Fig. 11 will show how much more simple a task it is to ventilate a colliery worked on the long-wall system, by a single continuous stream.

8. When the method of *coursing the air*, or carrying it through all the passages, was first introduced, it was only one single current which had to travel through the entire distance, sometimes amounting to thirty miles; and that which entered in the morning fresh and pure, emerged at night from its long journey clogged and heated and unwholesome. The last quarter of a century has wrought a vast change in the ventilation of coal mines, and one of the greatest improvements consists in *splitting the air*, or dividing it into a considerable number of separate currents or "runs," each designed for a different district and having a comparatively short distance to travel, whereby not only is the air preserved in a purer state, but a much larger quantity of it can be brought into play.

Skilful pitmen have also combined with this plan a division of the workings into compartments or *panels*, isolated as much as possible from each other by thick pillars of coal, and having separate ventilating currents, so that an accident occuring in one of them shall not necessarily extend to the others.

9. About three-fourths of the victims of an explosion are generally found to have been killed—not by the fire itself—but by the *after-damp* or mixture of gases produced by combustion. This produces the most fatal results, in consequence of the greater part of the workings being thrown "dead," or left without ventilation, when the force of the blast has destroyed certain doors or stoppings which drove the air into the interior of the mine. It remains, unfortunately, in most collieries, a desideratum to introduce such an arrangement of the air-ways as shall carry the ventilating current, without dependence on doors or frail stoppings, to the far end of the excavations, and thus preserve the lives of all those who may have survived the first violence of the explosion.

The working of seams which yield much fire-damp, *fiery coals*, must ever be attended with considerable risk; but the foregoing pages may suffice to show that science has been applied in a large scale to avert the constantly-impending danger. Much may yet remain to be improved; but suggestions for change are only likely to proceed usefully from those who have learned to appreciate the magnitude and system of the arrangements already carried into effect by the vigorous mind, the cool courage, and bodily endurance of the chiefs among coal miners.

LESSON IV.

RAISING AND PREPARING ORES.

1. The water which interferes with the operations of the miner, and the minerals which he breaks from their parent site, are brought to the surface by a variety of mechanical contrivances: worked, according to circumstances, by manual labour, horse-power, or engines driven by water or steam. The apparatus is often of amazing size and strength, and requires no little skill on the part of the mining engineer, to plan, fix, and work it to the greatest advantage. But in a sketch of the Art of Mining, necessarily so brief as the pre-

sent, it would be out of place to attempt to give the details, whilst the principles on which these applications are founded are described in the sections on Mechanics and Hydraulics. Thus, it need only be pointed out, that by a repetition of the common pump, pumping up from one cistern to another, we may draw the water from the bottom of the deepest shaft; and if one long beam or *rod* extend the whole way, to which the piston-rods of the pumps are attached at intervals, the once lifting of this "main-rod" by the machinery will cause all the pumps to make a stroke at the same time. But we must remember that such a rod, in some of the deeper mines of England and Germany, is no less than the third part of a mile in length; and when suspended by one end, and calculated to draw out several hundred gallons of water a minute, it may be imagined that all the strength and durability which wood and iron can give, have to be employed.

2. One of the greatest improvements introduced by the miners of Cornwall has been the substitution of *plunger* or forcing-pumps for the ordinary lifting-pump, by means of which the weight of the rods, in descending, forces upward the column of water, and the power of the engine is thus exerted simply to raise the rod itself. In this manner a mine of 300 fathoms in depth may be kept clear of water by nine sets of pumps, each of which raises the water through a height of little more than 30 fathoms: whilst the diameter, in different cases, may vary from 6 inches in comparatively "dry ground," to 18 inches in "heavily-watered" country, or even 40 inches, in the extraordinary case of the Alport Mines in Derbyshire, where a perfect river of water had to be combated.

3. Again, as regards the apparatus for "winding" or "drawing," *i. e.*, raising the mineral, it consists—on the smallest scale—of a simple windlass, by which one end of a rope is made to bring up a full, whilst the other lowers an empty bucket. But where, in large collieries, great amounts, as one thousand tons, are to be raised daily from a considerable depth, a convenient weight, say a ton, being lifted at once, the ropes, pit-

fittings, and engines, must all be of the highest degree of efficiency, and a speed of 1200 feet in a minute is often attained, coupled with great smoothness and regularity of motion.

Where only moderate quantities of material are raised, a horse-whim is employed, as represented in fig. 5. One or more horses walk round and round, as in a mill, raising the full bucket, whilst the empty one descends.

4. It may be remarked under this head, that it is usual, in coal mines, throughout Britain at least, for the men to be lowered and raised to and from their scene of labour by the same rope or chain that is employed for the extraction of the mineral. In metalliferous mines, on the contrary, their mode of ingress and egress is by a succession of ladders, generally inclined at a small angle. The latter method is slow and laborious, but gives rise to very few accidents in comparison with those consequent on the breakage of ropes and chains, or the other casualties which may occur when a man no longer trusts for his life to his own strength or coolness, but hangs utterly helpless at the mercy of the trustworthiness of the materials and engine-driver.

5. For the deepest mines, other elements have to be considered. So overpowering is the fatigue of daily climbing the ladders, that those of the miners who work very deep fall an early prey to various disorders, and are cut off in the prime of life: whilst it may be calculated that a very large fraction of their available labour is wasted in merely raising their own weight.

On the other hand, when they are lifted by a rope, a considerable time is employed, and expense incurred, in raising and lowering several scores or hundreds of men; and the latter plan is only advisable when, as in collieries and some iron mines, the whole of the complement work from the bottom of one shaft, and not, as in metalliferous mines, at a number of different levels.

6. Under these circumstances many suggestions have been made to relieve the copper, tin, silver, and lead

miners; and it is curious to observe that the urgency of the case led, almost at the same time, to the adoption of similar means in different regions.

In 1833, a miner of the Hartz Mountains, Mr. Dörell, suggested and carried out a plan depending on the alternating motion of two rods, like pump-rods, worked by a water wheel, and placed parallel to one another, some twenty inches apart. To these are attached small platforms, which stand opposite to one another at the end of the stroke made by the rods. A man wishing to ascend steps on to one—say the left-hand rod—and is raised 5 feet, whilst the platform, which stood opposite him at first, on the right hand rod, is lowered 5 feet. The change of position of the two rods by this time brings an upper platform of the right-hand rod opposite him, to which he steps across, just before it commences its ascending motion; and thus, alternately stepping from one to the other, a single man, or any number of men consistent with the strength of the machinery, may be raised to the surface.

7. This apparatus, more or less modified, was soon applied to many of the shafts in the same district, one of which, at the Samson Mine, has attained the extraordinary depth of 425 fathoms, or 2550 feet English.

In Cornwall, the premium offered by the Polytechnic Society of Falmouth brought forward several ingenious inventions, and in 1834 a prize was awarded to Mr. Loam for a plan independently suggested, but on exactly the same principle as the above. It was, however, not till 1842 that it was put in practice at Tresavean Mine, near Redruth; and although acknowledged to be consistent with true economy as well as humanity, the so-called "man-engine" has hitherto (1854) been brought into play only at two other mines in the same county. At one of these, Fowey Consols, it is simplified by having but one rod, from which the men step off to fixed stages in the shaft, during that part of the stroke which would not carry them in the desired direction.

8. In dealing with metalliferous ores the labours of the miner are far from concluded when he has brought them

"to grass," or to the surface. Almost all of them are too much mingled with foreign matter to be at once advantageously treated in the smelting furnace, for the production of metal. They require in the first instance to be washed, picked, broken up, and divided according to their character, both as mineral substances and as regards percentage of metal; and upon this the more or less elaborate processes of *dressing*, or mechanical preparation, are commenced, which with the majority of ores are indispensable, in order that they may be fitted for the operations of the assayer and the smelter.

9. Dressing of Ores.—Over a large portion of the earth's surface, natural causes have been at work to prepare, by mechanical means, certain minerals for the use of man. This is particularly exemplified by the heavy and indestructible substances, gold, platinum, and tin-stone. The upper part of the lodes in which these minerals were at first formed has been worn down, along with the parent rock in which they were encased, by atmospheric action exerted through long geological periods. The fragments have been washed down by winter floods, by streams and rivers, and spread at a distance over the lower land or along the beds of water-courses. The lighter and smaller particles have by this process been carried furthest, and the heavier and larger left nearer to the place of original deposit, or accumulated in cavities, whence the force of the stream has not been powerful enough to wash them out.

In this manner have two operations to a certain extent been effected: the once solid masses have been broken up into small pieces, and the heavier substances more or less separated from the lighter.

10. When ores are broken from the solid rock by mining, they must be submitted to processes more or less akin to the natural ones above mentioned; they have to be washed from the impurities which prevent their character being seen, to be broken up into small pieces, and separated, by taking advantage of their greater weight, from the refuse with which they are associated. A very great number of ingenious contrivances are

employed for those purposes, but differently carried out, according to the degree of purity in which it is desirable for the subsequent treatment by smelting that the ores of different metals should be obtained. Thus copper ores need only to be *dressed* until the resulting mixture contains 5, 6, or 8 parts of copper per cent., whilst tin and lead ores should be so far freed from impurity, that the smelter should receive them containing 60 or 70 parts of metal per cent.

There are some few ores in which several of the useful metals are so intimately mingled, that much greater complexity than usual must be introduced both into the methods of dressing and of smelting.

11. The first process, when the rough material is brought out of the mine, is to wash it with a stream of water, coupled with a plan of sorting it into different sizes, by means of a grate or riddle. The large masses must be *spalled* or broken up with a sledge-hammer, and the best portions picked out by hand, since it is an axiom that whatever can thus at once be selected as sufficiently pure is saved from great loss in the subsequent processes.

Next follows the reduction in size of the inferior kinds. Nothing should be broken smaller than absolutely necessary, since all powdered material suffers loss when brought in contact with water. Copper, lead, and zinc ores are generally ground in a "crusher," which reduces them to a size varying from that of a pin's head to that of a hazel nut. The machine for this purpose consists of two rollers of hard cast-iron, about two feet in diameter, revolving towards one another, and which can be kept closer or further asunder by a lever urged by a heavy weight.

12. Gold and tin ore, which occur most frequently in very small disseminated particles, require that the stone in which they are enclosed should be brought to a finer powder, and are therefore stamped. The "stamps" is a series of beams of wood or bars of iron placed upright, and having at their lower extremity each a "head" of cast iron, weighing from 300 to 500 lbs. These are raised by machinery in regular

succession, about a foot at a time, and then fall with their full weight upon the mineral which is placed beneath, and which cannot escape from the strong box containing it till it is pounded fine enough to pass through a grating with holes of a regulated size, by aid of a stream of water which continually flows through.

A large "stamps" with 100 such heads in a row, worked by a steam-engine or water-wheel, as in Cornwall or Hungary, produces so continuous a thunder that the visitor must escape to some distance before he can hear any explanation.

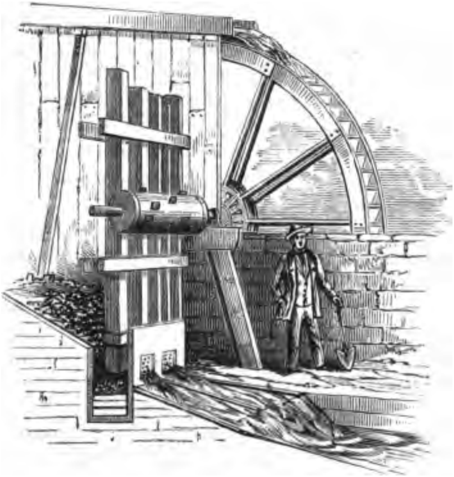


Fig. 15.

Fig. 15 is a small stamps as employed for tin ores.

It is only in some particular cases, as where silver ores are to be prepared for amalgamation with mercury, that some other plan is employed to reduce them to impalpable powder.

13. When the ore is thus broken up, and has been by other means sorted, more or less, according to the size

of the grains, the separation of the good from the bad, as it were, of the wheat from the chaff, is effected by taking advantage of the difference in specific gravity.

If the fragments are large, a sieve containing a small quantity at a time, is immersed in water and rapidly jerked up and down; all the contents being thus suspended for a moment, at each stroke the heavier settle first, and the process of *jigging* thus enables three or four divisions to be made, of which the uppermost layer, or the lightest, is generally discarded at once as refuse. When the grains are small or almost impalpable, as in "slime" ores, they are made to flow with a current of water over an inclined plane, so regulated that the richest or heaviest portion is deposited at the upper end, then the inferior, and lastly the worst at the lower end of the apparatus, and a frequent repetition of such "buddling," or some analogous process, brings the ore at last to the desired degree of purity.—WARINGTON SMYTH.

Vegetable Physiology.

BY EDWIN LANKESTER.

LESSON I.

ON THE ORGANS OF WHICH PLANTS ARE COMPOSED.

> "And he shall be like a tree planted by the rivers of water, that bringeth forth his fruit in his season; his leaf also shall not wither; and whatsoever he doeth shall prosper."

1. PLANTS and animals are called *organic* beings, because, they possess parts which are unlike each other, and which, performing different actions in relation to the life of the plant or animal, are called *organs*. Thus all the higher plants have leaves and a stem which have a distinct structure and perform different functions, and are hence called organs. Even the minutest plants and animals possess this difference of structure in their various parts, and present claims to the term organic. The small plants which consist of a single cell, and

hundreds of which are contained in a drop of water, are often covered with small hair-like organs called *cilia*, by means of which they move.

2. If we submit any organ or portion of an organ of a plant to the microscope, we shall find that, however uniform may be its external appearance, it consists of several different parts. These parts will at last be found to consist of little hollow spherical bodies, which are called *cells*. If the organ of an animal be examined in the same way, it will be found to present the same ultimate structure, the parts being all evidently made up of cells. It is the fact, of animals and plants being made up of these minute organs, that constitutes one of the great differences between *organic* and *inorganic* bodies.

3. As all the organs of plants are made up of cells, it is necessary, in order that we should understand the nature of these organs, that the structure and nature of these cells should be studied. Although from the time that the microscope was first used, it was seen that the organs of plants were composed of cells, it has not been till very recently that the importance of studying these organs has been recognised. We are indebted to two living German observers, Schleiden and Schwann, for drawing attention to the universal presence of cells as the bases of all parts of plants and animals. Schleiden was the first to investigate this subject, and he has not only shown how every part of a plant is made up of cells, but discovered the origin of these bodies.

In the cuts 4, 5, 6, and 7 of Fig. 1, will be seen a dark spot in the centre of the cells there represented. This spot was observed by our own great countryman Robert Brown, and called a "nucleus," but Schleiden pointed out the fact that this nucleus, or "cytoblast," as he called it, was the first part of the cell which was formed, and that all cells took their origin in this central mass. Although in many cases, and especially in the animal cells, this central part or "endoblast," as it has been termed by Mr. Huxley, assumes the form of a central nucleus—this is not always the case, as perhaps in the majority of instances in plants, it is diffused over the interior of the cell, and in this form has been called the "primordial utricle."

4. When cells are formed from the cytoblast, the walls rise up from its surface, and have the appearance of a watch-glass upon a watch. When, however, they originate from the primordial utricle, they divide in two, each portion containing a portion of the central mass. Cells dividing in this way are seen in 1, 2, 3 (fig. 1).

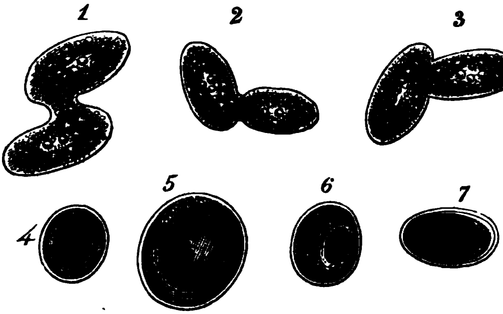


Fig. 1.

5. When the cells of plants are allowed to grow without any external pressure or interference, they generally assume the spherical form, as seen in the majority of those simple plants composed of but one cell. (Fig. 1.) This is, however, by no means constantly the case, for under the influence of pressure cells assume the forms of many-sided tissues, or they become elongated, and united together forming what are called vessels. The various forms presented by cells are seen in fig. 2.

6. Cells grow in two ways, either they take up into the interior of their walls the material of their growth, and thus they become large in size, or they deposit new matter in their interior. These deposits assume various forms, and often give a character to the appearance of the cell. The most common form which these internal deposits assume is that of a spiral fibre, which runs round the interior of the cell, as seen at *d*, fig. 2. It often happens, however, that this spiral fibre gets broken

up, and then various irregularities are seen in the inside of the cells and vessels, which gives them the appearance of being covered with dots or punctured by pores (*e*, fig. 2). These markings on the inside of cells afford an easy means of classifying the cell-work of which the organs of plants is composed. This cell-work is called the *tissue* of the plant; and we may divide the tissues of plants into cellular, and fibro-cellular, vascular, and fibro-vascular, according as they present those markings or not.

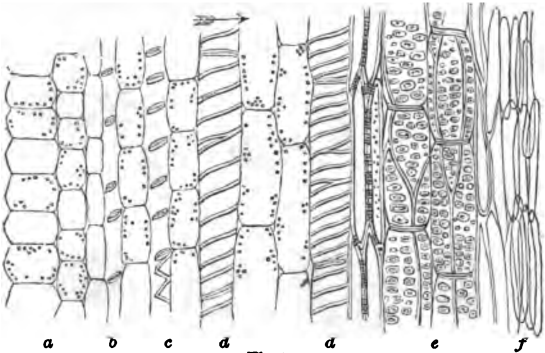


Fig. 2.

7. *Cellular* tissue is composed of single cells, and exhibits many forms. When the cells are so loose as not to press on each other and assume a spherical form, the tissue is *incomplete*. This is seen in the Red Snow Plant (fig. 1), and in the loose cellular tissue in the interior of many plants. The tissue is called *complete* when the cells press on each other. Regular pressure on all sides produces many-sided cells of various shapes. The most common form is a twelve-sided figure, which on being cut through represents six sides. Such tissue is seen at *a*, fig. 2. When the sides of the cells grow out and form regular projections, which meet other cells of the same kind,

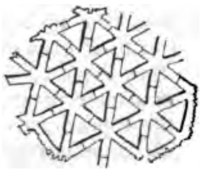


Fig. 3.

the tissue is called *stellate*. This is well seen in the stem of the Common Rush (fig. 3). Sometimes cells from pressure assume a tabular or flat appearance, as seen in the cellular tissue composing the medullary rays of the stem of some plants, and which cabinet-makers call the silver grain.

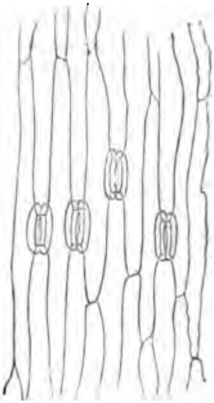


Fig. 4.

8. The outside of all plants is covered with a layer of cellular tissue, which is called *epidermis*. It is composed of more definitely-formed and usually smaller cells than the other parts of plants. The use of this tissue is to confine the moisture of plants, and prevent too rapid evaporation from their surface. Upon the epidermis which covers the leaves are seen minute pores, or openings, called *stomates* (fig. 4). The openings of these pores lie between two semilunar cells, which render these organs very obvious under a good magnifying glass. On examining the tissue beneath one of those pores it is found to be loose, and there can be no doubt that the use of these organs is to allow of the passage of fluid from the tissues of the plant. They are found most abundant in the leaves of plants that are thin and dry, whilst in succulent leaves and on the stems of succulent plants, as the Cactuses (fig. 5), they are absent.

Fig. 5.

9. The epidermis gives rise to a number of organs upon its surface. These are called by a variety of names according to the appearance they present. When one or two or more cells project like a little pimple they are called *papillæ*. Such projections are seen in the little glistening bodies which cover the ice-

plant. The most common form which these appendages assume is that of *hairs.* The surface of plants assume different appearances, according to the form and number of the hairs they present. Sometimes they are short and strong, at others times they are long and silky. Sometimes they are straight and single, at other times they are branched and even stellate in their form. One of the most singular properties they possess is that of stinging, which arises from the cells producing a poisonous secretion. The cells containing the poison are generally placed at the base of the hair (fig. 6).

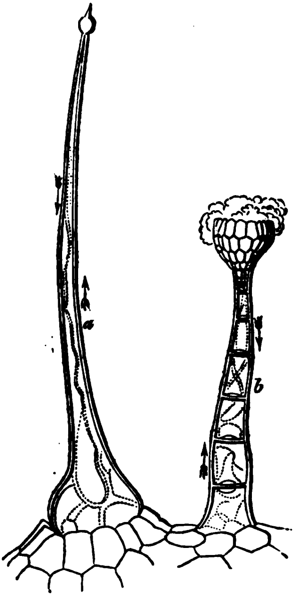


Fig. 6.

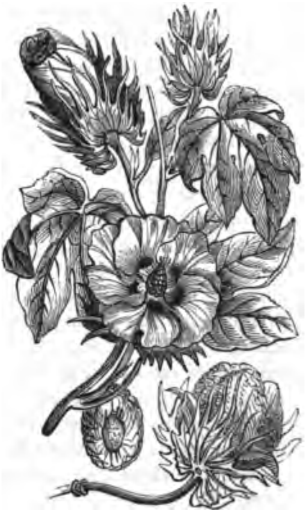


Fig. 7.

10. The epidermis is continued into the interior of the fruits of plants, and in this situation they also produce hairs. Thus the cotton hair which is commercially of so great importance to this country is produced in the interior of the fruit of the Cotton Tree (fig. 7).

This hair appears to get twisted in its growth, and upon this twisting depends the facility with which it can be converted into a yarn, and used for spinning textile fabrics.

11. Another kind of epidermal organs are *prickles*, which are distinguished from thorns and spines, by the facility with which they are torn from the parts on which they grow.

12. When the cellular tissue of plants is cut into, considerable spaces are frequently found between the cells (fig. 8). These are called by various names as *intercellular spaces*, *passages*, or *cavities*. The hollow stems of the Hemlock and the Dead Nettle are examples of such spaces, which have resulted from the more rapid growth of the woody parts of the stem. The little cavities in which the sweet-smelling oils of plants, as the lavender, and rosemary, and the oil of lemon in lemon peel, are contained, are called *receptacles of secretions*. In water plants they contain air to enable the plant to float.

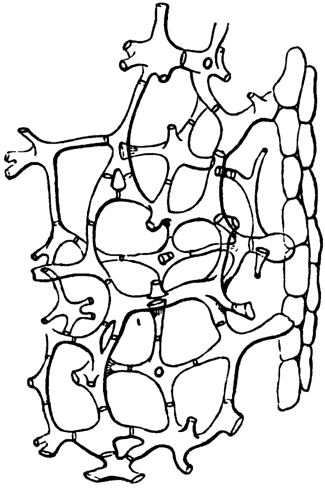


Fig. 8.

13. Fibro-cellular tissue, is not so common as the last, but is found in some forms of Orchids in the Cactus tribe, and in the inner layer of the anther-case of the stamens of most plants.

14. When cells unite together and form an elongated tube they are called vessels, or vascular tissue (*c a e*, fig. 2). These are found with or without fibres. The cells which constitute what is called woody or ligneous tissue have no spiral fibres in their interior. This kind

of tissue forms the great bulk of the stems of plants, and constitutes the wood or timber which they afford. In such plants as the flax, hemp, and cocoa-nut, these tubes are so loosely held together that they may be separated, and are then used for weaving the various kinds of linen, hempen-cloth, and cocoa-nut fibre fabrics. They are also formed into string and ropes.

15. The vessels which contain spiral fibres, or portions of them, present a great variety of appearances (fig. 2), and have obtained the names of *ducts*, *dotted ducts*, *porous vessels*, *spiral vessels*, *tracheæ*, and *glandular woody tissue*.

16. One set of vessels are branched, and in plants with milky juices are easily seen to convey a current of sap. They have been supposed to form an important system in the structure of the plant, but their true nature and functions are still doubtful. They are called laticiferous tissue, or vessels of the latex (fig. 9).

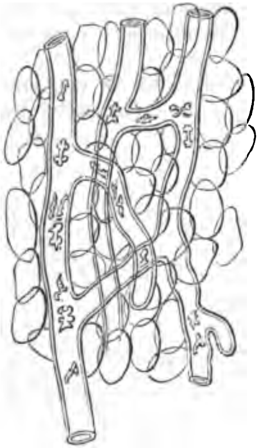


Fig. 9.

EDWIN LANKESTER.

HYMN ON THE SEASONS.

These, as they change, Almighty Father, these
Are but the varied God. The rolling year
Is full of thee. Forth in the pleasing Spring
Thy beauty walks, thy tenderness and love.
Wide flush the fields; the softening air is balm;
Echo the mountains round; the forest smiles,
And every sense and every heart is joy.
Then comes thy glory in the Summer months,
With light and heat refulgent. Then thy sun
Shoots full perfection through the swelling year:
And oft thy voice in dreadful thunder speaks,

And oft at dawn, deep noon, or falling eve,
By brooks and groves, in hollow-whispering gales
Thy bounty shines in Autumn unconfined,
And spreads a common feast for all that lives.
In Winter awful thou! with clouds and storms
Around thee thrown, tempest o'er tempest rolled.
Majestic darkness! on the whirlwind's wing,
Riding sublime, thou bid'st the world adore,
And humblest nature with thy northern blast.
Mysterious round! what skill, what force divine,
Deep-felt in these appear! a simple train,
Yet so delightful mixed, with such kind art,
Such beauty and beneficence combined;
Shade, unperceived, so softening into shade;
And all so forming an harmonious whole,
That, as they still succeed, they ravish still.
But wandering oft, with rude unconscious gaze,
Man marks not thee, marks not the mighty hand
That, ever busy, wheels the silent spheres;
Works in the secret deep; shoots, steaming, thence
The fair profusion that o'erspreads the spring:
Flings from the sun direct the flaming day;
Feeds every creature, hurls the tempest forth,
And, as on earth this grateful change revolves,
With transport touches all the springs of life.

* * * * * *

Should fate command me to the farthest verge
Of the green earth, to distant barbarous climes,
Rivers unknown to song; where first the sun
Gilds Indian mountains, or his setting beam
Flames on the Atlantic isles; 'tis nought to me;
Since God is ever present, ever felt,
In the void waste as in the city full;
And where He vital breathes, there must be joy.
When even at last the solemn hour shall come,
And wing my mystic flight to future worlds,
I cheerful will obey; there with new powers,
Will rising wonders sing. I cannot go
Where universal love not smiles around,
Sustaining all yon orbs, and all their suns;
From seeming evil still educing good,
And better thence again, and better still,
In infinite progression.

THOMSON.

Animal Physiology.

BY ROBERT JAMES MANN.

LESSON I.

ANIMAL TEMPERATURE.

> "His going forth is from the end of the heaven, and his circuit unto the ends of it: and there is nothing hid from the heat thereof."

1. **Warmth is Essential to Life.**—As travellers go into the colder regions of the earth, they find fewer and fewer living creatures, until, at length, in the frozen waters that surround the pole, scarcely a plant, or an animal is to be seen during the greater part of the dreary year.

The warmth on the earth's surface is mainly dependent upon the influence of the sun. Sunshine falls on the ground, and the ground grows warm under its presence, exactly as a book, or a piece of wood does, when placed in front of a burning fire. But the amount of heat the terrestrial surface acquires, is in proportion to the directness with which the sun's rays strike on the ground, and to the length of time they continue to do so without interruption. Hence, the earth's surface gets hotter and hotter, during a summer's day, and then colder and colder during the ensuing night. In India the sun sometimes heats the earth's surface so much, that it is half-way between the temperature of freezing and boiling water. The wooden furniture of houses then warps and shrinks, as it would if placed in an oven. Glass has been known to crack. Under such circumstances, people are compelled to lie in the shade, and do nothing during the middle of the day. The slightest exertion seems to be too much for their oppressed frames. Excessive heat is as unsuitable to the offices of life, as warmth is essential for their healthy performance.

2. The degree of heat, that people find it most pleasant to live in, is that which is experienced in the shade, during most English summer-days. Men of science,

in order that they may have a measure of temperature, divide the difference of warmth that separates freezing from boiling water into one hundred and eighty equal parts, and then term each of these parts a degree of heat. They thus say that boiling water is one hundred and eighty degrees hotter than ice. Now the agreeable warmth of the English summer-days is thirty of these same heat degrees hotter than freezing water. This is denominated, in the language of science, a temperature of sixty-two degrees, for the heat-reckoning is made to begin thirty-two degrees below the freezing point. In such a temperature men can sit still with very little clothing on them, and yet do not feel cold. When the air is colder than sixty-two degrees, they are mostly driven, by their feelings, to adopt some artificial plan to increase the warmth of their frames.

Over the greater part of the earth's surface, the heat is commonly less than this agreeable temperature of sixty-two degrees. In England it only reaches such a height, in the day-time, during four months of the year. Consequently, men are driven to adopt various devices for keeping themselves sufficiently warm. Of all these devices, the most common and the most successful one is the burning of artificial fires. They set light to fuel placed in iron grates, and then husband the heat which is produced during the burning of the fuel, by confining it in closed rooms as long as they can. In this way they make the air of these closed rooms take up the heat set free from the fuel, and then live in the heated air.

3. All kinds of fuel, which are capable of giving off heat when burned, contain more or less of two distinct principles; of these principles, one is the solid, black substance, known as *carbon;* the other is the light, inflammable gas, called *hydrogen,* which is the same that is employed in inflating balloons. Coal consists almost entirely of these two bodies, mingled together. The carbon constitutes its dense, black mass: the hydrogen is the light vapour that escapes from it, when it is greatly heated, and bursts into flame. When coal is burned, it slowly wastes away, and gradually disappears

from sight. The reason for this is, that it is surrounded by a strong, although invisible agent, which is able to seize upon it piecemeal, and carry it away. This invisible and strong agent, that surrounds the coal, floats in the air; it is indeed itself a part of the air. It is called *oxygen* gas.

4. Now the little imperceptible atoms of which oxygen gas is composed, possess a peculiar affection for the analogous atoms, both of dense, solid carbon, and of light, gaseous hydrogen. This affection is held in control and rendered inoperative, so long as the carbon and the hydrogen are cold. When these are considerably heated, however, it comes into active play. Oxygen-atoms then seize on carbon-atoms and float off with them, in intimate combination with themselves, the two assuming the air-like gaseous state, and becoming what is known as *carbonic acid.* Oxygen-atoms also seize on hydrogen-atoms and float away with them, the two being transmuted by the union into watery vapour. The carbonic-acid and watery vapour, formed when coal is burned in the presence of oxygen, are carried, with the stream of heated air, up the chimney, and are scattered, in the condition of thin, invisible vapour, abroad upon the wind. Such is the wonderful process that takes place whenever a combustible substance is burned—dense, visible matter is changed into light invisible vapour, or air, and the change is brought about by the combined influence of two things—the presence of great heat, to give a start to the transformation, and the presence of corrosive oxygen, the chemically-powerful portion of the atmosphere, to keep up the process of transformation when once set going. Every one knows how the corrosive property of the air eats into bright iron, and wastes it away in rust. The same property eats into combustible coal when made red-hot, and wastes it away in vapour, which floats off into the air, instead of adhering all over its surface, as a coat of rust.

5. The animal body requires a temperature that is considerably higher than sixty-two degrees, in order that the blood may circulate freely, and all the several

actions, upon which life and health are dependent, may be carried on effectually and well. When the frame feels comfortably warm, the external air being at a temperature of sixty-two degrees, its own internal heat stands at one hundred degrees of the heat-scale. Hence, it is apparent that the living body has some independent source, from which it can acquire the heat it needs. It is dependent neither upon the sun, nor upon artificial fires, entirely. When surrounding substances are warmed to sixty-two degrees by those influences, it has within itself thirty-eight degrees more of warmth. We have now to ask where the body gets this extra-internal heat from, if it comes neither from the sun, nor from artificial fires; *whence* is it derived? The answer to this question is a singularly interesting and surprising one. The body carries about, in its interior, a little furnace of its own, which it keeps duly supplied with suitable fuel, and which it blows up continually with gently-puffing bellows. The fuel of the body is furnished from the food, and the puffing bellows, by which this fuel is made to keep burning, are the lungs.

6. The food, that animals swallow, contains within itself two different kinds of substance. The one kind is of a *plastic* nature—that is, of a nature that suits it for building-up structure. The other kind is exclusively of a combustible nature, that is of a nature that suits it for burning. Now the combustible portion of food is a true fuel, as much so, indeed, as coal itself. Nothing else is done with this fuel, after it has been received into the body, but burning it. It is never made into anything, intended to remain as a useful organ; it is never turned to any purpose, save its own especial one of warming the system, into which it has been admitted. It is then consumed, exactly as the coal of a burning fire is consumed. But wonderful to say, it is not only like the coal, in the fact of its consumption, it is also like it in its nature. It is principally made of the self-same carbon and hydrogen, and is originally prepared by plants growing in warm sunshine. But that this may be made perfectly clear, it will be necessary to state what the combustible

principles are that are taken in by animals as ingredients of their daily food.

7. Flour, which forms the bread of man, is made up of two distinct parts. If it be washed well with water, and kneaded by the hand all the time, a quantity of white powder is suspended in the water, and carried off by it when poured away; but there remains around the hand a lump of sticky, glutinous paste. This paste is the plastic or structure-forming part of the nutritious flour, that was placed in it by the Almighty, in order that it might be able to build up the organs of animals when they feed on it. But the white powder, that is washed away in the water, has no formative power in it. It is merely a fuel that is designed to be employed in the production of heat. It is called *starch*, from an old German word that means "stiff." It received this name on account of the convenient property it possesses of stiffening linen, when it is dissolved in boiling water. Each little atom of starch, when separated from its neighbours, is found, by the chemist, to be a cluster of still more minute atoms of carbon, hydrogen, and oxygen. Nearly one-half of the substance of starch is carbon and hydrogen, the combustible elements present in coal. Hence, starch burns very readily. This will be at once seen, if a little powdered starch be dropped upon red-hot coals.

8. There are several other principles in the different kinds of food in common use, that are combustible, as well as starch, and that can be made no other use of but to be burned. These are all, indeed, of nearly the same nature as starch, and contain even larger proportions of carbon and hydrogen. Sugar is one of these substances. Oil, in every variety, is another. Butter and fat are oil that has accumulated, in animal bodies, in larger quantity than can be at once burned off, and that therefore can be taken in and employed for heating purposes, by other animals. All these different substances, starch, sugar, and oil, were primarily made out of carbonic acid and water, by plants growing in sunshine, just as wood is. But when they are thus made by plants, portions of heat are also stored away in

them for future use. This heat it is that is extracted from them, and rendered sensible when they are burned in the animal body. Starch, sugar, and oil, like coal, can contain more heat in a hidden state than the separated elements, out of which they are composed, and indeed require the presence of that heat for their own composition. Consequently, when they are resolved back, in the process of burning, into those elements, the concealed heat becomes superabundant and superfluous, and heats the body, in whose vessels and cells it finds itself when it is set free.

LESSON II.

THE LUNGS.

"All the while my breath is in me, and the spirit of God is in my nostrils; my lips shall not speak wickedness, nor my tongue utter deceit."

1. The solid food that is taken into the stomach is, by digestion, changed into a liquid substance. In this form, it is then imbibed into the blood-vessels, and circulated to all parts of the frame. The liquefied food that is thus circulated in the body is called the blood. But, as the food has two offices to perform, the one being the building up of the various structures and organs, and the other, the support of the warmth of the body by a process of burning, the blood must also comprise within itself two different kinds of material, the one plastic, and the other simply combustible. The combustible part of the blood is formed out of the starch, sugar, oil, and fat of the food. The starch and the greater part of the sugar are turned, by the process of digestion, into a sort of fat, but a little unchanged sugar finds admission into the blood. It is the sugary and fatty parts of the blood that are burned, as a fuel, in the internal furnace of the body, for the support of its heat. There is nothing extraordinary in the fact that a fluid should be able to burn, because it is well-known that oil of every kind is combustible, at the same time that it is a fluid. Oil flows freely up in the wick of a lamp, and yet burns when it reaches the top,

producing a great amount of heat and light. Just in the same way, the oil of the blood flows freely along in the crimson stream, and yet burns when subjected to the influence that is designed to bring out its heat.

2. The combustible matter of the blood does not burn rapidly, as coal does when heaped on a large furnace. There is no visible fire produced anywhere by its burning; it smoulders in the slowest possible way. The reason for this is found in the fact that the combustible matter of the blood is able to begin to burn at a very low temperature, instead of being forced to remain unchanged until a very high one is reached. Coal remains perfectly unchanged until it has been made very hot indeed; after it has been heated many times more than boiling water it still continues unconsumed. The fuel of the blood, on the other hand, never gets hotter under any circumstances than 102 or 104 degrees of the heat-scale, and yet it smoulders and burns at that temperature. It is especially prepared for this service of slow consumption and change, for its little atoms are hung so very loosely together that the slightest influence is sufficient to push them on into transformation. In fact, the fatty matter of the blood burns, while still mingled with the general stream of the circulation. It finds in that stream corrosive oxygen, and it deposits in that stream alike the carbonic acid, the water, and the heat, that are the products of its burning.

3. The blood-vessels, then, are the internal furnace of the animal system. We have seen what the provision is that is made for keeping up the supply of fuel to this blood-furnace from time to time. Combustible food is swallowed, digested into a fluid state, and then carried into the blood. We have now to observe what the arrangements are that have been made for keeping the furnace burning in its slow way; how it is that it is blown up and kept smouldering on, so that the due supply of heat may be extracted from its consuming fuel, and be furnished to the body of which it forms a part.

The heart is divided into two distinct halves, and each of these halves has its own system of vessels. One of them, the left one, belongs to the nutritive service of the body. Its tubes run wherever nourishment needs to be supplied. But the other half, the right one, belongs solely to the heating service. Its tubes run exclusively to one particular organ, especially and wonderfully fitted for supplying air-blasts to the circulating, liquid fuel, and for receiving the products of its burning, the waste smoke and vapour, so to speak, which would be stifling and injurious if not conveyed away by some chimney-like outlet. The organ, which thus serves at once as the bellows and chimney of the furnace, that supplies the temperature of the living animal, is the *organ of respiration*, or, in other words, *the lungs*.

4. The great arterial trunk, or blood-vessel, which issues from the right side of the heart, bent on the heating service, very soon divides into two separate branches. In the figure (fig. 1), R represents this right chamber of the heart; and *a* the main vessel, or arterial trunk which issues from it, and divides into the separate branches, *a* 1 and *a* 2. Now these branches subdivide into yet smaller tubes, and then get plunged into large fleshy masses, *l* and *l*, which form the bulk of the lungs. But out of these fleshy masses, other blood-vessels also come, which unite into venous trunks, *v* and *v*, and then end in the left, or opposite chamber of the heart. The consequence of this arrange-

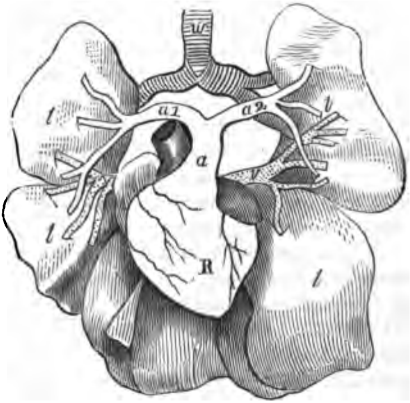


Fig. 1.

ment is, that when the right chamber of the heart contracts upon the blood that is contained within it, that blood is forced through the vessels, *a*, into the lungs, and then through the lungs into the vessels, *v*, and so into the left chamber of the heart, that is set apart for the nourishing service. The vessels, that take the blood out of the right chamber of the heart into the lungs, are called the pulmonary arteries, those that convey the blood back from the lungs to the left chamber of the heart are called the pulmonary veins. In the lungs themselves, the blood that has been just forced out from the right chamber of the heart, passes by small connecting tubes, provided for the purpose, from the pulmonary arteries into the pulmonary veins. After the right chamber of the heart, R, has contracted upon its charge of blood, and thrown it forward into the lungs, it dilates and receives a new charge of blood, that is poured into it by vessels that come from the system at large, and that are therefore called the systemic veins. Half the blood contained in the body is, in this way, passing through the lungs on the heating service, while the other half is passing through the rest of the organs on the nourishing service. But we must now trace the course of the first half, and see what happens to it while it is in the interior of the respiratory organ.

5. The arteries and veins are not the only tubes that enter into the lungs. A large pipe, which commences in the mouth, passes down through the throat, and divides into branches, which run into the fleshy mass of the respiratory organ. In consequence of being filled with air, this tube is called the *windpipe*. It is at once distinguished from the blood-vessels by its structure; they are made of soft, yielding walls, but the windpipe and its branches are made of hard, firm gristle. The air-tubes are composed of rigid gristle, instead of soft and yielding material, because by this means they are made to stand always gaping and open for the reception of air. In the figure, *w* represents the windpipe and its branches coming down from the mouth, and passing into the fleshy substance of the lungs on either side.

The branches of the windpipe subdivide more and more as they dip into the substance of the lungs, getting finer and finer as they go, just as the trunk of a tree divides into smaller and smaller twigs, and they end at last in little rounded extremities bearing the form sketched in figure 2 (p. 98). These rounded extremities of the branches of the windpipe are blind, that is, they have no other opening than the one which connects them with the tube. They are called *air-cells*, because they are little chambers filled with air, but they are not formed of hard, gristly walls like the air-tubes. The gristle disappears just where the air-tube passes into the cell, and this is then made up of a fine delicate membrane prolonged from the lining of the tube. The hard air-tubes cannot be squeezed in, but the soft air-cells can be easily pressed, so as to make their cavities of smaller size; when the air-cells are compressed, air is drawn out of the lungs through the air-tubes and windpipe. When the air-cells are dilated, fresh air rushes in through the windpipe and tubes into the lungs. Now this alternate compression and dilatation of the air-cells takes place regularly in the act of breathing. The lungs are lodged in the cavity of the chest, which has moveable walls and a moveable floor that are heaved out and in, and up and down, by muscles provided for the purpose. When the chest is expanded by these means, the air-cells are enlarged, and when the chest is contracted, the air-cells are diminished, and in this way fresh air is being constantly pumped into and ejected from the interior of the breathing organ. The air-cells are of an inconceivably minute size; it is probable that twenty or thirty thousand might be easily packed away upon the face of a shilling. But their vast number makes up for their diminutive dimensions. It has been calculated that there are six hundred millions of them in the lungs of a man.

6. But small as the air-cells are, there are other structures connected with them that are very much more minute: when the cells are greatly magnified by the microscope, and carefully examined, it is found that they are covered by a delicate network of vessels, not so wide

as themselves by some twenty times, laid closely all over their thin soft walls. These vessels are the terminations of the pulmonary arteries; they are indeed the connecting tubes that run from the pulmonary arteries into the pulmonary veins. In fig. 2, *a*, a pulmonary artery, is seen running along the wall of the air-tube, branching out into a network of vessels, *n*, on the wall of the air-cell, and then returning back along the air-tube at *v*, a pulmonary vein. So long as the right chamber of the heart continues contracting upon its contents, blood is made to flow continuously through these delicate little channels. But when it does so, the blood is only separated from the fresh air contained within the cavity of the air-cell by the finest conceivable film of membrane, that forms at once the coat of the vessel and of the cell. The film is able to keep the blood from running out of the vessel, but it is not able to keep the blood and air, which it divides, from mutually influencing each the other. Oxygen, from the air, exudes through the film, and mingles with the blood, and at the same time carbonic acid and vapour, with which the blood is overcharged, exude through the film and mingle with the air.

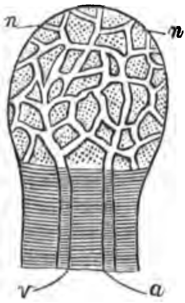


Fig. 2.

7. Here, then, are at once the breath to fan the fire, and the chimney-outlet whereby the waste, formed from the burning of the fuel, is removed. Pure air goes into the lungs with each breath, but moist impure air is returned at each expiration; for it loses a portion of its oxygen and receives instead vapour and carbonic acid, that are thrown out from the blood into the air-cells as exhalations. Air, which is carried to a burning fire as a draught, is conveyed to the circulating blood as a breath. Carbonic acid and watery vapour, which ascend the chimney over a burning fire, and so escape into the air, are exhaled from the blood into the air-cells of the lungs, and

are then expired from the air-cells into the atmosphere.

But the lungs are after all merely the organs by which air is conveyed to the blood, and by which carbonic acid and watery vapour are removed from it. The burning of the fuel, that is, the conversion of the oily matter into carbonic acid and watery vapour, under the corrosive influence of oxygen, really takes place in the blood during its motion in the channels of the circulation from place to place. But it has been seen that when combustible matters, containing carbon and hydrogen, are changed into carbonic acid and water, heat is set free, and as the conversion takes place in the blood during its circulation, it is here of course that heat is set free. The blood, therefore, becomes the hotter for its presence, and carries its heat with it wherever it goes; but the blood goes everywhere throughout the frame, the entire body, consequently, is warmed by the blood, and thus the temperature of the animal is kept higher than the temperature of the surrounding air.

8. The lungs are constructed entirely with a view to the bringing of air and blood into close and free communication; they consist of air-tubes and blood-vessels bound up together in an investing substance: their fleshy mass is composed of these structures and of nothing else. The air-tubes branch out into the mass, as the rootlets of a plant branch out in the porous ground. Blood-vessels run in and interlace all over the ends of the air-tubes, and run out again, and the branching air-tubes and interlacing blood-vessels are interwoven and united into one spongy substance, by means of a covering and connecting membrane. All this is done in order that oxygen may be freely supplied to the blood, and that by its agency combustible matter may be burned and a genial warmth produced. Such is the structure and such are the functions of the lungs.

LESSON III.

STRUCTURE AND FUNCTIONS OF THE LIVER.

"Whether therefore ye eat or drink, or whatsoever ye do, do all to the glory of God."

1. The plastic, or nutritive portion of the blood furnishes the material of all the various organs of the body. But this material needs to be changed from time to time. As vital organs are used, their substance is wasted and removed, and new substance is brought to take the place of the old. The old, worn-out matter mingles with the blood, but it cannot be allowed to remain there, for if it did, it would soon choke up the entire mass and render it poisonous to healthy action. It is taken away from the organs because it is spoiled and no longer of use; it therefore must not be kept in the channels of the circulation, and carried over and over again to positions where its presence is not required. Worn-out material is separated from the blood by a series of organs contrived for this especial purpose, and called "secreting" organs, on account of their separating powers. All these separating organs are made upon one general plan. They all consist of clusters of little vesicles, hanging about the minute branches of blood-vessels, and of small tubes that get collected into common ducts, which end in some of the natural outlets of the body. When blood is made to course through the blood-vessels, portions of it are drawn out from the stream into the interior of the little living vesicles, these vesicles then drop, like ripe fruit, with all their contents, into the tubes provided for conveying the secretion away, and there burst and mingle the substances with which they are gorged into one general mass. Different kinds of secreting organs separate different kinds of substances from the blood. Some are of more importance to the system than the rest, on account of having in charge the removal of very noxious products; among these very important separating organs, the liver holds a principal place.

2. It is venous blood, or, in other words, that which is flowing back towards the heart from the various organs

of the body, that most requires purifying, because it is the most loaded with the waste of the system; hence it is a vein that supplies the purifying liver with blood. All the several veins that are returning from the stomach and digestive organs get gathered together into one trunk, which then plunges directly into the substance of the liver. This trunk is called the portal vein, because it enters in this way into the liver. The portal vein branches out in the liver just as the pulmonary artery branches out in the lungs. When its tubes have become tolerably small, they are distributed like the meshes of a net, and then yet finer tubes run inwards from these meshes towards the centre, where they unite and form the commencement of another system of vessels, which then get larger and larger, and carry the blood out of the liver. These vessels that convey the blood from the liver are called the hepatic veins, from hepar, the Latin word for liver. This arrangement of the blood-vessels of the liver is shown in fig. 3, which is a greatly-magnified view; *p p* represents one of the terminal meshes of the portal vessels that bring the blood into the liver: *t t* are the fine tubes that run from the meshes in towards the centre, and *h* shows the beginning of one of the hepatic veins that receive the blood from the fine twigs of the portal vessels and carry it out of the liver.

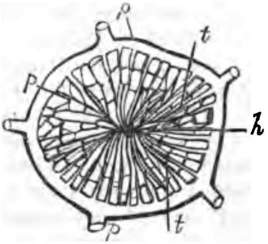


Fig. 3.

3. Thus, then, the liver, like the lungs, consists of blood-vessels that branch out in its substance, into very fine twigs, and then unite again to form larger and fewer branches, until they end as they commenced in one or two main trunks. In the lungs, the fine twigs of the blood-vessels are spread out round the walls of their air-cells, because it is the business of the organ to mingle intimately blood and air. The object of the arrangements in the liver is not the mingling of two things

together, but the separation of one thing from another. Hence, the fine twigs of the portal vessels are spread out round the walls of secreting vesicles. The spaces intervening between the meshes of the portal vessels, *p p*, and the origin of the hepatic veins, *h*, are filled with little living cells, which imbibe their peculiar secretions from the blood, and which multiply with great rapidity. Broods of these cells are continually dropping off from the mass like over-gorged leeches, and when they do so they fall into channels provided for their reception. The material, which the liver-vesicles separate from the blood, is termed *bile*, and the channels, which receive the vesicles loaded with their charge of bile, are called bile-ducts. The bile-ducts are interlaced among the small twigs of the blood-vessels inclosed (at *t t*) between the meshes of the portal vein. The bile-ducts are in their turn gathered up from these spaces into larger and larger tubes, which finally end in one trunk, that pours its contents into the digestive canal. The liver, made up of these interlaced blood-vessels and bile-ducts with their appended secreting vesicles, is bound up in its own coats, and conveniently packed away beneath the lungs, as one large fleshy mass.

4. The bile, that is separated from the blood-vessels in the liver, and conveyed out of the organ by the bile-duct, is a thick yellow liquid, of a peculiarly combustible nature; it is, in fact, a kind of oil, made soapy, and of easy suspension in water, by admixture with soda. It may therefore be converted into a fuel and burned in the heating service, although no longer of any use for plastic purposes. The worn-out, combustible principles are first passed through the liver and separated from the blood, because they are noxious to the various delicate organs of the frame, in their then condition. But, in the liver, they are converted into bile, a substance that is no longer hurtful; this bile is then poured into the digestive canal, and then taken up therefrom with the digested food, and again mingled with the blood; in the blood it is burned for the production of heat. The elements of
le is composed cannot accumulate in the blood

without very injurious results being produced. But the bile itself often does collect there to a very considerable extent without effecting any mischief.

5. But bile also assists in the performance of the digestive function, while it is retained in the digestive canal; it seems to fit the starch and sugar of the food, just received, to undergo the process of burning, when they are taken into the circulating stream. As the lungs constitute the blast apparatus and chimney of the furnace of the system, the liver is really the fuel-preparing apparatus that supplies the furnace. It capacitates the various combustible matters, that are added to the blood, for burning under the oxygenating blasts of the breath. In this sense the liver and the lungs are really auxiliary organs, each is essential to the perfect operation of the other, and to the support of the elevated temperature of the animal frame.

6. **Fresh Air essential to Health.**—When air is breathed, its energetic member, oxygen gas, finds its way into the furnace of the animal system, that is, the circulating blood,—and there unites itself with the combustible matter that has been supplied from the food and from the waste of the various structures, corroding it into a vaporous exhalation, and carrying it off in this condition with the breath. In order that this fuel-burning and blood-purifying process may be carried on efficiently, two things are carefully adjusted each to the other. As much fuel is supplied to the blood as can be consumed by the oxygen, and as much oxygen is furnished as suffices for the consumption of the fuel. The dimensions of the bellows, and the frequency of the blasts, are arranged in accordance with the strength of the air that is to be employed, the quantity of fuel that is to be burned in the furnace, and the amount of heat that is to be procured out of the burning. Fresh air contains in round numbers twenty per cent. of oxygen. The human lungs take in and expel, at each act of ordinary breathing, about twenty cubic inches of air, and fifteen breathings are made every minute, four strokes of the heart being apportioned to furnish the due amount of blood to each

of these. A full-grown man, with his heart beating eighty times, and his breathing repeated fifteen times, in each minute, manages to keep his body at a temperature of one hundred degrees of the heat-scale: the supply of the fuel, and the force of the air-blast are just sufficient to insure such a result. But in effecting this, he passes 300 cubic inches of air through his lungs in each minute, and spoils them, so far as their fitness for re-employment in a like respiratory office is concerned: the air is taken into the lungs fresh and pure, but it is returned from them robbed of a fourth part of its oxygen, and loaded with a hundredfold more carbonic acid than it ought to have. Pure air contains twenty per cent. of oxygen, and the twentieth part of one per cent. of carbonic acid; but after it has been passed through the lungs in breathing, it is returned to the atmosphere with only fifteen per cent. of oxygen in it, and with the proportion of the carbonic acid increased to five per cent. A single pair of full-grown human lungs robs the air of about twenty cubic feet of oxygen by twenty-four hours' breathing, and throws into it about twenty cubic feet of carbonic acid gas instead.

7. Carbonic acid gas is not the only thing that is exhaled from the lungs of breathing animals, the expired breath is also loaded with vapour; this is seen in cold weather to condense into visible mist as it issues from the mouth. The vapour is principally water that has been poured out from the blood into the pulmonary air-cells; but it is not water alone: neither water or carbonic acid possesses any odour. The expired breath, however, has a distinctly-marked odour. There is in it some peculiar exhalation that has been formed in the blood, and that has been thrown out from it, through the respiratory air-tubes, together with water and carbonic acid.

8. Air, that has been breathed by living animals, is thus changed in three important particulars: it is deprived of a portion of its oxygen, it is loaded with an undue proportion of carbonic acid, and it is contaminated with a quantity of animal exhalation. So long as men live

in the open air of the country, this is not of much importance, because the bulk of the entire atmosphere is so vast that all the impurities that are poured into it are lost in its immensity, and because the oxygen is there restored as fast as it is removed, by the purifying agency of growing plants. Notwithstanding the countless millions of living creatures that are always at work absorbing oxygen, and throwing off carbonic acid and impure exhalations into the air, its composition is never perceptibly affected in the mass. The winds drift the impurities everywhere throughout its substance, and then green leaves and frequent showers remove and destroy them. In the open country, the air always has its twenty per cent. of oxygen; and its charge of carbonic acid and animal exhalation is always so slight as not to be at all appreciable to any but the most refined examination.

9. In the interior of dwellings and in confined spaces the case is altogether different. The causes of contamination are there in full activity, and the natural movements of the air are so interrupted that the impurities produced continue to accumulate from time to time. There, too, there are no green leaves to remove the carbonic acid and to restore the lost oxygen; neither is there any rain to wash away the more volatile exhalations. A single full-grown man, in twenty-four hours, changes 250 cubic feet of pure air into air that has five per cent. of carbonic acid in it, besides other animal exhalations, and that has lost one quarter of its oxygen. If he were shut up in a small chamber, seven feet square and seven feet high, and no fresh air were allowed to enter during a day and a night, all the air contained would in that time be changed into the condition of air just expelled from the lungs. But no animal can continue to live in air that contains five per cent. of carbonic acid, besides being loaded with other impure exhalations, and being deficient in purifying oxygen. In such an atmosphere, the blood gets more and more burdened with injurious matters that ought to be removed by the respiration of pure air, and this impure blood circulates throughout the system and

oppresses the various vital organs; and first of all, the most delicate amongst them, the brain and other centres of nervous action: heaviness and languor gradually overpower the mind, these then pass into sleep and insensibility, and the sleep is one from which there is no awakening. If fresh, pure air be not speedily supplied the end is inevitable death. When men are confined for lengthened periods in air that cannot be changed, they are compelled to breathe the refuse exhalations of their own frames over and over again, in the place of the genial atmosphere Providence has furnished for their use, and they die in consequence, poisoned by what they breathe. An atmosphere deficient in oxygen, and overcharged with carbonic acid, is sufficient alone to produce the most dire results. But this becomes even more powerful for evil when it is also filled with an accumulation of the volatile exhalations that escape from the blood with the carbonic acid.

10. It is to such exhalations that the spread of various fevers and other infectious disorders is mainly due. Wherever contagion of this kind becomes very active in the production of disease, deficient ventilation is always at the bottom of the mischief. The worst forms of infectious disorder may be put an end to, by taking care to keep the patients affected by them in only the purest air. In all cases of this kind, the poison is conveyed into the blood of unaffected persons through the lungs; it enters their air-cells with the air, and then passes through the delicate walls of the blood-vessels. Abundant dilution with air destroys the power of this poison and makes it of no avail.

LESSON IV.

SUFFOCATION.

"Thou takest away their breath, they die and return to their dust."

1. WHEN the body of a living animal is completely immersed in water, air is entirely excluded from the lungs all at once. The chest is expanded in the usual way, but water rushes into the mouth, and comes into

contact with the opening of the windpipe in place of air. As this liquid is, however, entirely unfit for the performance of the offices of respiration, it is not admitted into the respiratory organ—the opening of the windpipe closes against it with spasm. Strong efforts continue to be made by all the muscles concerned in the breathing operations, but these efforts are useless. More and more uneasiness is experienced, the sense of suffocation becomes extreme agony, but this is of very short duration. Venous unoxygenized blood alone is sent through the lungs, and onward into the system, and this cannot support the vitality of the various organs. The capillary vessels of the lungs, therefore, after a time, cease to send forward their liquid contents. The heart beats more and more languidly. The brain becomes torpid, and faintness and insensibility ensue. The body at the same time loses its heat in consequence of its internal furnace being stifled and extinguished, and the resulting coldness tends to the destruction of vitality in every part.

2. Death results from drowning, chiefly (1) because venous blood is sent where arterial blood ought to go; (2), because the heart ceases to be able to continue its contractile movements when its natural stimulus is withheld from it; and (3), because the degree of temperature that is essential to the operations of the various organs is no longer maintained. But the movements of the heart continue after all other appearances of life have been effaced. The pulse may be felt beating when all consciousness is gone, and when every trace of breathing has been lost, and the contractile powers of the muscular organ remains for some time even after its perceptible movements have been stopped. Hence, it is possible that life may be restored by the adoption of judicious means, although it seems to have fled from the stilled frame. In all cases of drowning it is suspended before it is destroyed, and so long as it is only suspended, the vital operations may be renewed. No case of drowning is hopeless until the contractile power of the heart is lost. People have been recovered from apparent death, even five hours after breathing has been stayed.

3. Whenever animation is suspended in consequence of immersion in water, there are three general principles that ought to be kept in view, while making the attempt to recall the dormant power. (1), Pure air must be admitted to the face as freely as possible; (2), the contractile powers of the heart must be attempted to be roused; and (3), the warmth which can no longer be supplied from within, must be communicated from without. The mouth and nostrils should be carefully wiped and cleansed in order that nothing adhering about them may impede the passage of air into the chest. Persons must not be permitted to crowd closely round. The body should be conveyed to the nearest dwelling, with the head and shoulders supported in a raised position, and should then be immediately stripped, and, if possible, placed in a warm bath at blood-heat, or this not being attainable, it should be dried and wrapped in heated blankets. Bottles of hot water or hot bricks should be placed in the armpits, over the stomach, between the thighs, and at the feet. A heated warming-pan, covered with flannel, and moved along the back, proves a very effectual addition to these operations. The skin should also be briskly rubbed with the hand or hot flannels, and spirits of hartshorn be occasionally passed backwards and forwards beneath the nose. So soon as the power of swallowing is recovered, a teaspoonful of warm water should be given, and then small quantities at a time of warm wine, or weak brandy-and-water also warm, in order that the renewed activity may be kept up by gentle stimulation; but great care must be taken not to administer enough of such agents to produce more excitement than is just sufficient for the end in view.

4. If, in a very short time after the employment of these various measures, the movements of the chest do not recommence, the attempt may be made to produce them artificially, and fresh air may be pumped into and out of the air-cells. First, the chest and abdomen should be forcibly and steadily pressed, until about one hundred cubic inches of air are driven out from the lungs; then the tube of a pair of bellows is

to be placed in one nostril, which is to be pressed round it with the hand, and then, whilst the other nostril and the mouth are closed, and the bony piece that can be felt in front of the throat (the larynx) is pressed back by the fingers to close the swallow, about one hundred cubic inches of air are to be blown into the lungs, these operations being alternately repeated during at least half an hour before hope is laid aside. In most cases, if these proceedings are adopted before the vital contractility of the muscles is lost, the air forced into the air-cells of the lungs renders the blood in the pulmonary capillaries arterial; this blood then begins to pass onwards, the circulation is gradually renewed, the heart answers to its accustomed stimulus, and resumes its pulsations. A gentle sigh is breathed, the chest commences to heave again on its own account, and life once more assumes its rule.

5. Mere deficiency of oxygen, in air that is breathed, leaves the blood overcharged with combustible matters that ought to have been removed; the furnace gets clogged with fuel that cannot be burned, and the fire consequently burns very dimly and inefficiently. If air that contains twenty per cent. of oxygen can effect the burning of four ounces of fuel in the blood, by a certain number of breathings, and in a given time, air that contains only fifteen per cent. of oxygen will not effect the burning of more than three ounces of fuel, in the same number of respirations, and in the same period. A reduction of five per cent., in the proportion of oxygen present in the air, acts practically, exactly as a diminution of the capacity of the lungs, to the extent of one quarter. would; or as the diminution of the frequency of the breathing by one-fourth. It deranges the admirable adjustment that has been made of the powers of the digestive organs to the dimensions of the respiratory apparatus, and of the dimensions of this apparatus to the properties of the respirable air. Such a reduction, therefore, invariably causes disorder and discomfort to take the place of comfort and of health.

6. In inhabited rooms fresh air is generally left to find its own entrance for the purposes of respiration, through

crevices accidentally remaining in doors and windows. So long as large fires are kept burning in open grates, within such rooms, this answers tolerably well, because then, very much more fresh air is compelled to pass through the rooms, than any number of persons that can conveniently dwell in them will ever require for respiration, and the carbonic acid and volatile emanations that result from their breathing, get gradually diffused amidst this moving air, and are carried away with it. Fires, burning in open grates, cause an abundant ventilation of the rooms in which they are placed by making the air, contained in the shaft of the chimney, lighter than the air which is pressing to get in at every external crevice by its own weight. Air lies piled up against every door, and every window, trying to run in at their crevices as water would do if placed in the same position; but the air without cannot run in at these crevices so long as the air within refuses to make way for it; the elasticity of the air within the room acts as a cushion of resistance and keeps it back. If, however, a fire is lit within the room, and there be an open chimney to allow of the escape of the smoke, the air contained within the chimney-shaft gets considerably heated, and is at the same time expanded and made lighter, bulk for bulk. This lighter air then becomes unable to resist the pressure of the colder air trying to force an entrance into the room below. The opening of the chimney becomes a weak point in the resisting arrangements, and through this weak point the warmer air is squeezed by the greater pressure of the colder air below. Both the warm air in the chimney, and the cold air outside the room, tend towards the earth in virtue of their weight, but the cold air tends more forcibly than the warm, on account of being a heavier substance. Both, however, are pressing on the air contained in the room, consequently this air is caused to flow in the direction in which the least pressure is exerted, that is, it flows up the chimney, pushing the light heated column before it, and the cold air around gets into the room through every little passage that it can find.

7. The air gets slowly changed in inhabited rooms where no fires are burning, provided free inlets and free outlets are arranged for its passage. The opening for the outward passage is best made somewhere near the ceiling, because then the light volatile exhalations from the lungs that rise towards the upper part of the room, are the most readily and surely removed. It is a very common mistake, in badly-contrived rooms, to make the upper sashes of the windows fixtures, so that they cannot be drawn down, and to provide no compensating outlets anywhere above. In such rooms the air is scarcely ever in a fit state to be breathed. In making arrangements to secure the perfect ventilation of apartments, it should always be borne in mind that air must go out as well as come in, or the purpose cannot be effected. An opening for the admission of air is of no use whatever, unless some other has been provided, in a convenient position, for the escape of that which is to give place to the new arrival: air will not flow into any room until an equal quantity has been driven out to make way for it. Fresh air will find its way in with equal facility either by high or low openings (if it be colder than the air contained within the apartment), provided there be but a sufficient space afforded for the escape of an equal quantity of the warmer air from the room.

8. Dr. Arnott has shown that a most efficient ventilation may be provided for close apartments by making an opening in the chimney of the room near the ceiling, and adapting to this opening a plate, so balanced as to allow air to flow from the room into the chimney, but to prevent it from moving in the opposite direction. In order, however, to insure the perfect operation of this ventilating valve it is necessary that the throat of the chimney over the fire, should be narrowed, and that there should be a free admission of cold external air, by a low inlet, otherwise the fire is apt to derive a portion of its air-supply from the ventilator, bringing down with it smoke from the chimney. When the inlets and outlets are properly adjusted to each other a portion of the warm air from the room escapes through

the fire, carrying with it carbonic acid, and another portion laden with the lighter exhalations, flows through the ventilating opening. When they are not properly adjusted, and there is a deficient space for supply compared with the outlets, the escape will always be through the fire in preference to the ventilator, and the latter may even be caused to furnish a downward draught.

9. A certain amount of exercise is essential to the perfection of the respiratory act, as well as the presence of uncontaminated air. The capacity of the lungs, the frequency of the respiratory movements, and the properties of the air are so adjusted to each other, that animals should live active lives. The breathing is made more frequent, and the blood is caused to course through its vessels with augmented speed by muscular effort. Consequently, more combustible matter is removed from the blood during such exertion, and more heat is produced. If a deep inspiration is drawn in the place of a shallow one, the air is found to contain at the end of the expiration a considerably higher proportion of carbonic acid than it does after ordinary expirations. The proportion occasionally becomes as high as nine per cent. The gentle and shallow movements of ordinary respiration do not unload the blood of all the combustible matter it ought to lose, but when quickened respiration and circulation are induced, the shallow breathings become deep ones, more blood is forced through the pulmonary vessels, more air is pumped into the air-cells, more oxygen gets into the blood, and more combustible matter is removed from it by exhalation. Brisk exercise in the open air is almost as important an influence as the perfect ventilation of dwellings in the preservation of health.

R. J. Mann.

Food.

BY LYON PLAYFAIR.

LESSON I.

USES OF FOOD.

1. Both plants and animals, while they live, require to be supplied with *food*, for if that is kept from them they soon die. In this chapter we are to read about the food of animals only, and to learn of what it is made up, and to what uses it is applied.

2. When the dead body of an animal is slowly heated, much water flies off as steam, and a dry mass is left which, on being put in the fire, partly burns away, while a small portion remains and cannot be burned. The portion that burns is called *organic matter*, and contains carbon or pure charcoal, hydrogen and oxygen, the two bodies forming water, and another element called nitrogen, which forms $\frac{4}{5}$ths of common air, the other $\frac{1}{5}$th being oxygen. The part of the dead body that did not burn is called *inorganic* or mineral matter, and is known to exist chiefly in the bones of animals, and in less quantity in their fleshy parts.

3. The organic part of animals consists of many substances, and although each of them is made up of only four elements, these are arranged in various ways, so as to form bodies quite unlike each other; flesh, blood, skin, horns, hair, tendons, feathers, all consist of these four elements, grouped differently.

4. Animals during life are constantly changing and throwing off their parts, which must be replaced by food. But as the latter does not contain flesh, skin, or horns, ready made, there are processes in the body by which simple kinds of food are converted into these complex forms. Science is yet a long way from knowing completely how such changes take place, but enough is known to show what portions either of vegetable or animal food are used for building up the structure of an animal body.

As the organic part of an animal contains the four elements—carbon, hydrogen, oxygen, and nitrogen—any part of the food used to build it up must also contain these four elements. If any one of them were absent, the structure would be imperfect, and could not be completed.

Both in vegetable and in animal food we find two classes of materials. One of these classes contains the whole four elements required for the formation of the animal body; the other contains carbon, hydrogen, and oxygen only, the nitrogen being absent. The latter class can therefore obviously not be used in the structure of the animal organs, and are in fact employed for a different purpose, which will be explained hereafter. In the meantime let us examine a little more closely the class of bodies containing the four necessary elements.

5. The various substances in this class bear a close relation to each other, whether they are found in vegetable or animal food. The *fibrin* obtained by stirring fresh blood with a stick resembles the *fibrin* from the juice of a cauliflower; the cheese got by adding vinegar to milk is quite like the cheese formed on adding the same acid to water which has stood over peas or beans; the albumen which forms the white of the egg is nearly the same as that found in a cabbage. The gluten got by kneading flour contained in a muslin bag, exposed to a stream of water, gives a good instance of this class of bodies in vegetables. Although trifling differences may be detected between these substances according as they are had from vegetables or from animals, they may for all practical purposes be considered as really the same among themselves, and as being almost identical in composition with the flesh of animals. By this is meant that if the cheese of milk or of peas, the fibrin of blood or of cauliflowers, the albumen of an egg or of cabbages, were all dried and given to a skilful chemist, along with some dried flesh, he would find in all not only the four elements carbon, hydrogen, oxygen, and nitrogen, but actually in the same proportion to each other, so that if they had not been marked he could not tell one from another, or state

from mere analysis of their organic portion which was flesh and which was vegetable. The general name given to this class of bodies in food is *flesh-formers*, because their use is to form the main parts of the animal body.

6. The similarity in nature between flesh-formers being known, the process of nutrition appears simple. It was always easy to see how a flesh-eating or carnivorous animal subsisted, for, eating flesh of the same nature as its own body, it was like feeding upon itself. But now when we know that vegetable food contains flesh-formers also, the nutritive process in a vegetable feeder, or herbivorous animal, is as simple as in the former case. The animal in fact finds, so far as regards composition, though not as to arrangement, its flesh ready formed in the plant, and eats enough of the latter to supply as much flesh as was wasted from its body during the day. Looking at this a little more closely, it will appear that plants really always form the flesh for animals, for, although there are carnivorous beasts, they subsist on vegetable feeders which had their food from plants, and therefore the latter give really in the first place the flesh both to the herbivorous and the carnivorous animal.

It will be shown afterwards that different kinds of food contain unequal quantities of flesh-formers, but the latter, so far as regards nutrition, are the same, whether they reach the animal through the vegetable or in the apparent form of flesh. In the case of a hunt there is much muscular force exerted both by the hunter and the hunted ; but the original structure of both, and the supply of their wasted parts, may come either from the animal or from the vegetable flesh-formers. Thus, an omnivorous animal—a man—mounted on an herbivorous animal—a horse—attended by carnivorous animals—dogs—pursues a vegetable-feeding hare or a flesh-eating fox. Hence we see that flesh-formers, to sustain strength, may either come immediately from vegetables or from animals, although in the first place they must always come from the former.

7. But it was stated that a second class of bodies in food

contained only three elements—carbon, hydrogen, and oxygen, the element nitrogen being absent. As all organs in the body contain nitrogen, they cannot be built up by this portion of food; what is its nature and what its use?

This second class of substances in food is known to us as sugar, gum, starch, and fat, and other things like them. Their use is to support the breathing or respiration of animals, and to keep up the heat of their bodies. The heat of the air changes from one day to another, and is very different according to the country and climate. In the Arctic and Antarctic regions it is intensely cold, and in the tropical regions near the equator, it is on the contrary warm. But the body of a man, or of another animal, keeps the same amount of heat while in a state of life and health, whether it is placed at the equator or transported to the poles. As animal heat does not vary with the difference in temperature of the surrounding air, there must be within the animal itself some means of keeping up its heat, and of producing more of it under one condition than in another. The fuel which thus keeps up the heat of the body is chiefly substances in food free from nitrogen, the starch, sugar, gum or fat; they are actually burned in the body just as they would be if thrown into a fire, only that they are burned in such a way that flame does not appear, although the same amount of heat is given out during their combustion. If these substances were thrown into a fire they would take up the oxygen of the air that streamed into the fireplace, and would unite with it, producing heat, and forming a gas called carbonic acid and water. In fact the carbon present in them, by uniting with the oxygen of the air, forms this carbonic acid, and the hydrogen also taking up oxygen forms water; the gas and the steam fly up the chimney.

8. Exactly the same process takes place in the body of an animal; the lungs introduce air into the body for the purpose of burning the vegetable or animal fuel taken as food. An ordinary man inhales about three thousand gallons of air a day. During the course of the year he takes

into his body seven hundredweight of air, or more than five times his own weight. But as the body of a man in good health weighs nearly the same at the end of a year as at the beginning, it is clear that the air which is breathed in must again be breathed out; but the breathed-out, or *expired*, air is not the same as the *inspired* air. In short, about one-fifth of the oxygen of the inspired air is found to have been taken away, and is replaced by the gas, carbonic acid, the same gas that forms, when common coal, sugar, starch, gum, or fat is burned in a common fireplace: in the latter it is sent up the chimney after burning, and in the body it escapes by the mouth.

The air which entered the body has burned some carbon in it, and must have given out much heat in doing so; by measuring the quantity of carbonic acid gas expired by a man in a day, it can be calculated that the whole carbon in the blood would be burned away in about three days. When an animal is without food, the air taken in by the lungs burns the flesh and the blood, and carbonic acid continues to be produced until it dies. But when food is taken, the air inspired burns that and not the body. The parts of the food usually consumed in supporting heat are those free from nitrogen, and it is chiefly in the absence of these, as in the case of starvation, or partly in flesh-eating animals, that the flesh-formers, or nitrogenous ingredients of food, are burned: the fuel which supports heat of animal bodies is chiefly fat, sugar, starch, and gum. Some idea may, perhaps, be formed of the large amount of heat thus produced in the body of a man when it is stated that every year there is as much heat formed in him as would raise about twenty thousand pounds of freezing water to the boiling point.

9. If the task were given to us of keeping a room at a temperature of seventy degrees, all the year through, we must burn very different quantities of fuel in it at different times of the year, and according to the manner in which the room was used. In winter much fuel must be heaped on the fire, in summer a small quantity would suffice, and varying amounts would be requisite

according as the room was in use; as, for example, whether it was chilled by external influences, from the opening of the doors and windows. This task is assigned to each of us, as regards our own body, which is a chamber always to be kept at a temperature of ninety-eight degrees, both in summer and in winter, and whether sheltered from or exposed to the inclemency of the weather. In order to obtain uniformity, man has learned by habit to adjust his food so as to put more or less fuel into the body, and the products of different countries naturally aid him in suiting himself to varying circumstances. Thus the fruits of tropical countries, in which the natural heat renders less necessary a large amount of fuel in the food, contain only about twenty-two parts in the hundred of carbon, while the whale blubber and fatty bodies consumed by the natives of the Polar regions, have as much as eighty parts in the hundred of the same element. The changes of circumstances produce a large difference, not only in the character, but also in the quantity of food taken as fuel. The native of Bengal may be satisfied with a handful of rice and a little fish for a meal, while Parry, Ross, Cochrane, Richardson, Saritcheff, and other Arctic travellers, tell us of remarkable cases of voracity, which find their explanation in the intense cold, compelling the introduction of a large amount of fuel to keep up the heat of the body. The Samoyedes are said to eat about eight or ten pounds of meat at a meal, washed down with a quart of train oil, and flavoured, when they can be had, with a dozen of tallow candles. Ross says that the Esquimaux eat ten pounds of fat meat and drink ten pounds of oil at a meal. Parry gives similar accounts; and Cochrane declares that he has seen a Yakut eat forty pounds of flesh in a day. Admiral Saritcheff says he also knew a Yakut who consumed in one day the hind quarters of a large ox, twenty pounds of fat, and a proportionate quantity of melted butter for his drink. Now, incredible as these accounts appear, there is no greater difference between the quantities of food consumed in the polar and tropical countries than there would be in the amount of fuel required to keep rooms, of equal size, at the same heat, in these two parts of the world.

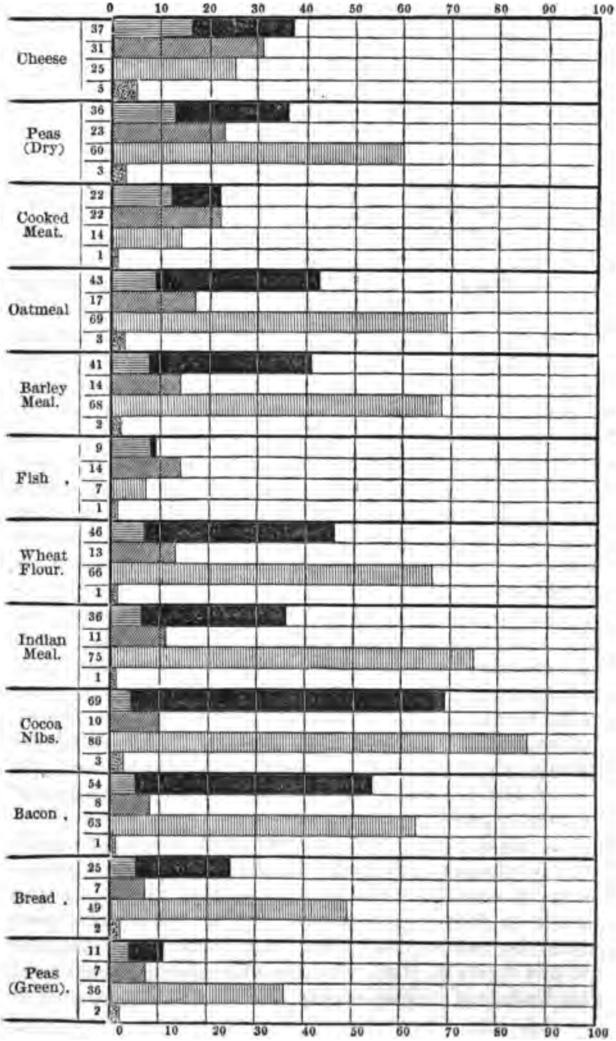
LESSON II.

COMPONENTS OF FOOD.

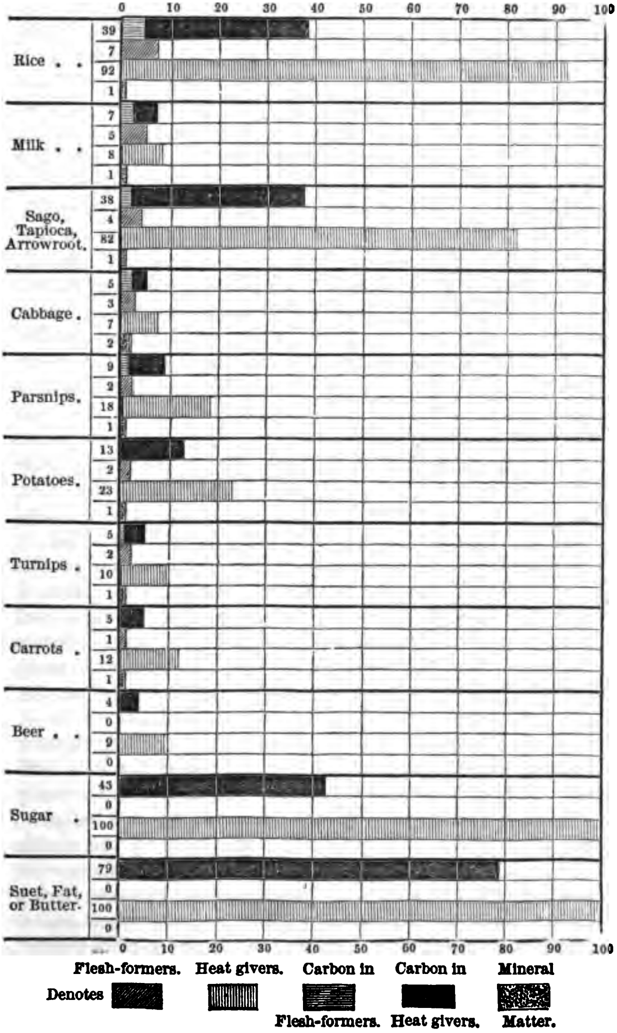
1. WE have now glanced at two divisions of the parts of food—the first division consisting of substances to build up the parts of the body, and the second division to keep up the animal heat required to enable it to perform its duties in life; a third division, fitted to supply the mineral matter also present in all animals, can only be glanced at in this place. A man, weighing about 150 pounds, has within him no less than 113 pounds of water, 21 pounds of substances containing nitrogen, about 6¼ pounds of fat free from nitrogen, and 9¾ pounds of mineral matter. The ten pounds, in round numbers, of mineral matter are made up of various substances, among which are phosphorus, sulphur, fluorine, soda, potash, lime, magnesia, iron, and silica: of course they all enter into the blood by means of the food or water, and the blood distributes them through the body to various parts which show a peculiar affection for them. The red colouring substance in the blood, and the black colouring matter of the eye, appropriate the iron; the silica, or flinty matter, is seized by the horn, nails, hair, or feathers; the brain takes much phosphorus, the hair much sulphur; the bones extract phosphate of lime and a little fluorine, the teeth showing a preference for the latter; the flesh loves to unite with phosphate of magnesia and potash, while the cartilages prefer the phosphate of soda: thus, throughout the body, the mineral ingredients of food have important duties to perform.

2. Having explained the three main classes into which the substances in food may be divided, it is now necessary to consider them when together, as they usually occur in food. In common diet all the three classes must be eat together; and experience has taught man to mix food; so that by taking more of one class in one kind of food he may supply what is wanting in another

CHIEF INGREDIENTS IN



VARIETIES OF FOOD.



kind; for if he attempted to feed on one class alone he would certainly die.

To explain this, a table, showing the differences in the composition of various kinds of food, is given at p. 120.

The horizontal lines at the top and bottom of this table refer to 100 parts—it may be 100 ounces or 100 pounds of each kind of food mentioned in the table. The relative amount of the three classes in each food is shown by differently-marked bands—a diagonal shading indicating the first class or flesh-formers; a perpendicular shading the second class or heat-givers; and a spotted shading the third class or mineral ingredients. But as the heat-givers may produce either much or little heat, according as they contain much or little carbon, there is still another band to show how much of this element is in the food; the horizontal shading, expressing the quantity of carbon in the flesh-formers, and the black, the quantity in the heat-givers. If we want to find out how rich a food is in any of these three classes, we have only to put a pencil or a ruler perpendicularly against the end of the band denoting the class, and where the pencil crosses the upper or lower horizontal lines we read off the numbers of parts of this class in 100 parts of the food. If we measure bread in this way it will be found that it contains, in 100 parts, 7 parts of flesh-formers, 49 parts of heat-givers, and 2 parts of mineral matter. The two former contain between them 25 parts of carbon. In order to make the table more easy for reference, the readings are also given in a column before the shaded bands.

3. It is impossible in such a table as this to give more than a general idea of the nature of food, for it is difficult to find two samples even of the same food exactly alike in composition. In the case of cheese for instance, the kind expressed in the table is that used by the middle classes, and containing less butter, but more flesh-forming matters, than is found in the cheese used by the higher classes such as Stilton and Cheddar, but more butter and less flesh-forming matters than in skim-milk cheese. The same plan of taking moderate samples throughout the construction of the table has been followed in order

that, as far as our information goes, average samples of the food may be displayed. The table is far from being perfect, and may be much improved when more varieties of the same food have been examined by chemists.

4. In looking at this table, striking differences will be found. Thus, cheese has a long line showing the amount of flesh-formers to be thirty-one parts in the hundred, while cooked meat has twenty-two parts, cabbage three parts, potatoes two parts, and carrots only one part. Sugar and butter have no diagonal shading at all, and therefore contain nothing to form flesh. Like differences will be found in the line denoting heat-givers. Although sugar and butter do not contain flesh-formers, it will be seen that their lines of heat-givers stretch across the whole table, proving how rich they are in this class though wanting in the former. Sometimes the differences in the composition of the various kinds of food arise from absolute poverty in the particular classes of ingredients, but at other times they are owing to one variety of food containing more water than another kind. Turnips, potatoes, parsnips, and carrots, stand low in the table, because they contain so much water. The potato has seventy-five parts of water in one hundred parts, the carrot eighty-three parts, and the turnip ninety parts. If this water were driven off by heat, the dried vegetables would be found to contain nearly as much flesh-formers as Indian meal. Cabbages in the same way, though low in the table, stand as high as peas when dried. But as the water is always present in vegetables, as they are found in the market, the low nutritive value must be expressed in the table. This is one reason why such a large quantity of watery vegetables can be consumed at meals. Men who live upon potatoes alone, often eat eight or ten pounds in the day; and a late pasha of Egypt is recorded to have frequently devoured a melon weighing forty pounds after his dinner, but in doing this, he really eat only two and a half pounds of dry matter, and drank thirty-seven and a half pounds of water.

5. In order fully to see the meaning of the table, the pupil must examine it at home; but enough has

been said to show that every kind of food has its own peculiar composition. Before any diet can be really nutritious it must contain the whole of the three classes into which food is divisible. Milk is an instance of a complete food, for it has the curd or cheese to form flesh, butter and sugar to give heat, and mineral matters to provide to the blood.

One hundred parts of milk contains eighty-seven parts of water, not quite five parts of curd or cheese, three parts of butter, four and three-quarter parts of a peculiar sugar, and less than one part of mineral matter. In this case all the three classes are present, and in the preparation of our daily diet we endeavour to imitate this complete food by making mixtures to furnish a proper supply of all three classes to the body. Lean beef, for instance, contains much flesh-forming matter though little of the heat-giving class, but we provide for the deficiencies of the latter by accompanying it with potatoes. Bacon, on the contrary, from its fat, is rich in heat-givers though poor in flesh-formers; we eat with it beans, peas, or greens, which supply its deficiency in the latter. For a like reason fat ham is taken with fowls, and rice with mutton. Thus man has learned by experience, without knowing the reason, to eat together two kinds of food which differ in their nature, the one supplying the class of ingredients wanting in the others.

When we know, as we have now begun to learn, in what these differences consist, our knowledge may be made useful in many ways by enabling us in future life to select cheap and nutritious food, and to make such mixtures as may be best suited for health and strength.

LYON PLAYFAIR.

Language.

BY ROBERT GORDON LATHAM.

LESSON I.

HOW TO COMPARE LANGUAGES.

"Many people of a strange speech and of a strange language whose words thou canst not understand."

1. **A Comparison.**—A little has been said about Language already in the first volume of this series; and

that little was said when we compared the Gipsy with the Englishman, and, again, the Englishman with the Welshman, Irishman, and the Scotch Highlander. The reader cannot do better than refer to these remarks, take his pen in his hand, and copy out, in four separate columns, the different names for the first ten numerals in the English, Gipsy, Welsh, and Gaelic languages. Thus—

ENGLISH.	WELSH.	GAELIC.	GIPSY.
One.	un.	aen.	yek.

And so on till he gets to

Ten.	deg.	deich.	tin.

When he has done this, he will have made a table for himself, a table by which he is enabled to compare no fewer than four different specimens of four different languages with each other.

Now this comparison should lead to a long train of thought; otherwise it will have been made in vain. It should lead to a long train of thought; for, undoubtedly, it suggests a great number of ideas, and originates a multiplicity of questions. In the first place, it is clear enough that the names for the several numbers in the four languages of the table are *different*. ONE is a different word from UN; and also different from AEN. On the other hand, however, the difference is only partial. It only extends to the *vowels*, OE, U, and AE. The *consonant* is the same throughout, being the sound of the letter N.

So that there is a certain amount of difference—

And, there is also a certain amount of likeness.

This is one of the facts that we have got from our comparison.

What is the next? It is only in *three* out of the four languages that we find this sound of N. In the Gipsy the consonant is K—the word being YEK. So that, in respect to the name of the numeral I, the Welsh and Gaelic are more like the English than the Gipsy is. So much for the *first* of the numerals.

2. The *second* tells us something new. The table runs—

ENGLISH.	WELSH.	GAELIC.	GIPSY.
Two.	dau.	do.	dy.

There is evidently a certain amount of likeness here, just as there was between the words *one*, *un*, and *aen*. And there is a certain amount of difference also, since none of the words are exactly the same, though all are very like each other. But there is more than this. The likeness runs through the whole four, extending itself to the Gipsy form *dy*, as well as to the English, Welsh, and Gaelic *two*, *dau*, and *do*.

3. *Three.*—Here the likeness repeats itself, the Gipsy word *tren* having this peculiarity. It is certainly different from *three* and *tri* in respect to its form; but is not, by any means, so certain of being a different word from them. It is rather the same word, with the addition of the sound of N, the same word with its shape altered. And, in this respect, the names for *three* differ from the names for *one;* inasmuch as YEK was, by no means, *one*, *un*, or *aen* in a modified form, but a wholly different word; a word with a separate history, and a separate origin of its own.

4. How far the names for *four*, *five*, and *six* differ or agree the reader is now left to discover for himself. He will, most probably, in the present state of his knowledge, consider that they differ. At *seven*, however, he will find what he has not found before, viz., the fact of the *Welsh* and *Gipsy* words, *saith* and *set*, being more alike than either the Welsh and English, or the Welsh and Gaelic. This is something to think about, until he proceeds onwards, through *eight* and *nine*,

5. To *ten*—where, instead of the *Welsh* and *Gipsy* (as they did in the case of *seven*) agreeing, it is the *English* and *Gipsy* (*ten* and *tin*) that agree, the Welsh and Gaelic disagreeing. On the other hand the Welsh and Gaelic agree between themselves—the names for *ten* being, in Welsh, *deg*, in Gaelic *deich*.

6. We have now seen the history of ten words in four different languages; or, if we chose, we may express ourselves differently, and say that we have examined four languages by means of a sample of forty words—ten words taken out of each. Four languages—forty words—ten words out of four languages, and no

more. Surely this is very little. The different languages of the earth amount to some hundreds, and in each of them there are some hundreds or even thousands of words; if we multiply these by one another, the sum that they come to is enormous: whereas the ten words of our table, multiplied by the four languages to which they belong, amount to forty—neither more nor less. What can we learn from such a miserable fraction of the great world of Language as this? What are forty words to the millions that are spoken by the sons of men, in England, in Europe, in the world at large? Nothing, or next to nothing. The pedant of antiquity, who, when he wished to sell his house, carried about with him a brick as a sample, was scarcely more unreasonable than a teacher, after the fashion of our table of forty words and four languages. This is what may be said by one who is over-hasty and unreflecting; but it is far from the truth.

7. The fact is that a great deal has been learned from these few words, forty in number—as much, perhaps, as if they had been four hundred. They have prepared us for finding in other words, besides the numerals, the same phenomenon of a certain amount of likeness, accompanied by a certain amount of difference, as we have found in the numerals themselves. They have also prepared us for finding in other languages, besides the four that have hitherto been under examination a certain amount of difference accompanied by a certain amount of likeness—just as we have found it in the English, Gaelic, and Gipsy. They have prepared us thus much—and they have done something more. They have, or, at least they ought to have, set us a-thinking about the reason for such a phenomenon. "Why," we should ask, "is the Welsh so like the English, and why is it no liker?" There is similarity, and there is difference, and both have to be accounted for; the one as much as the other.

8. Now this is just what has been observed elsewhere in respect to the varieties of the human species. The Gipsy, the Englishman, and the Negro had, each and all, plenty of points wherein they agreed with, and, at

the same time, plenty wherein they differed from each other. They all walked upright, spoke an articulate language, lived about the same number of years, and died at about the same age, upon an average. Yet their skins were of different colours, and their hair was of a different texture, in addition to which, their habits of life and civilization were widely dissimilar. In short, there was a difference and likeness, or the old story over again, likeness sufficient to place them in the same class when that class was a large one, and difference sufficient to distribute them over different divisions, when the class to which they belonged got divided. The house that held them was the same; each, however, belonged to a different room in it. The family likeness was the same throughout, but some were brothers and sisters, and some only fifteenth cousins. When we looked at his colour only, the Indian was liker to the negro than he was to the European; but when we looked at the texture of his hair, he was liker to the European than the Negro. And this is what we find in our tables. In the name for *one* the Welsh is liker to the English than the Gipsy; in the name for *ten* the English and Gipsy agree, whilst the Welsh and English differ.

9. Let us now exercise ourselves a little in the consideration of these differences, by asking questions, both respecting the languages (the four we have under notice) and respecting the varieties (also four under notice) of the human species.

a. Looking at our tables, and *taking all things together*, which of the four languages are the most alike, according, at least, to the showing or evidence of the numerals?

Answer. The Welsh and Gaelic. We may safely say this. Then,

b. Looking at our four varieties of the human species, the European, the Negro, the Indian, and the Gipsy, and *taking all things together*, which of the four most resemble each other?

Answer. The Indian and Gipsy. We may safely say this. Other questions, however, are less easily disposed of. It is by no means clear whether the Gipsy numerals are the most English or the most Welsh, nor yet is it altogether an easy matter to determine whether an Indian is most like an European or a Negro. His colour is the colour of the latter, his hair the hair of the former.

10. This should set us *comparing;* for whenever we have to *observe*, we have to *compare* also. This is a rule that applies to all parts of natural science, and to few more than to the natural history of man and language. Let us, in the present instance, compare the differences of language with the differences of hair, colour, form, and the like. We cannot, it is true, in the present state of our knowledge, go far in this direction, inasmuch as it is only a few varieties that have been noticed, and also a few out of many languages. Nevertheless, we may go far enough in the field of comparison to see what sort of phenomena it presents, and to understand their importance. Do the varieties of mankind that differ most in feature and form differ most in language also? Do those that differ least in language differ least in form and feature? Again, we have compared the different varieties of mankind with the different portions of the earth on which they lived; will languages bear the same comparison? I say that we cannot go far into this inquiry at present. It is best to wait a little: the subsequent volumes of the present series will assuredly give us our answer.

11. At present it is best to wait a little, and, in the meanwhile, reflect upon what we have seen in the way of *likeness* and *difference.* The likeness which we see between such numerals as the Gipsy, the English, the Welsh, and the Gaelic, and the difference between the Gaelic, the Welsh, the Gipsy, and the English. How can we account for the languages being alike? The simplest view of this question is to suppose that there is but one language for all those numerous populations whose tongues resemble each other. This is what we should maintain if the *likeness alone* had to be accounted for. In like manner, if the *difference alone* be under notice, we cut the matter short by saying "that dif-

ferent populations express the same thing differently, speaking absolutely different languages."

12. But neither of these views meets the facts of the case. There is difference and likeness combined, so many points of absolute identity, so many points of close similitude, so many points of distant likeness, and, finally, so many points of absolute difference and contrast. Thus, in the Gaelic and Welsh the words for three (*tri* and *tri*) are the same; the words for one (*aen* and *un*) much alike; the words for ten (*deg* and *deich*) distantly allied in form; and lastly, the words *one*, in English, and *yek*, in Gipsy, wholly distinct.

What explains such facts as these?

13. The view that we are now compelled to take is as follows. In order to explain the points wherein languages agree we must suppose that, *at some time or other*, they formed but one form of speech; whilst in order to explain the points wherein they differ, we must suppose that, as time went on, changes took place; by which means forms of speech, originally alike, became more and more separate and different from each other. Simple as this view may be, it explains a great deal; though I do not say that it explains everything—I only say that it explains enough for our present purpose. If languages were wholly unlike each other from the beginning, there would be no such similarities as we have observed. If languages were absolutely the same through all time, unchanging and unchangeable, there would be no such differences.

14. But it may be said that there is no occasion to trouble ourselves about these matters, inasmuch as the likeness we say so much about is *accidental*. Now, of all the erroneous opinions that are to be found in science, no one is half so erroneous or half so pernicious as this doctrine of *accident*. The word should be expunged from the student's vocabulary, just as Napoleon, when some half-timid officer told him that something necessary to be done but not very easy to do, was *impossible*, replied somewhat sharply, that there was *no such word as impossible in French*. So also there should be no such word as *accident* or *accidental* when we study language.

MISSIONARY HYMN.

FROM Greenland's icy mountains,
From India's coral strand,
Where Afric's sunny fountains
Roll down their golden sand;
From many an ancient river,
From many a palmy plain,
They call us to deliver
Their land from error's chain.

What though the spicy breezes
Blow soft on Ceylon's isle,
Though every prospect pleases,
And only man is vile?
In vain, with lavish kindness,
The gifts of God are strewn,
The heathen in his blindness
Bows down to wood and stone.

Shall we whose souls are lighted
With wisdom from on high;
Shall we to men benighted
The lamp of life deny?
Salvation! oh! Salvation!
The joyful sound proclaim,
Till each remotest nation
Has learn'd Messiah's name.

Waft, waft, ye winds, his story,
And you, ye waters, roll,
Till, like a sea of glory,
It spreads from pole to pole;
Till o'er our ransomed nature,
The Lamb for sinners slain,
Redeemer, King, Creator,
In bliss returns to reign.—HEBER.

LESSON II.

SKETCH OF THE CHIEF LANGUAGES EITHER SPOKEN OR STUDIED IN GREAT BRITAIN.

"That every tongue should confess that Jesus Christ is Lord to the glory of God the father."

1. BEFORE we go farther into the subject of the last lesson, it may be advantageous to improve our know-

ledge of the languages already brought under notice, languages which it has been convenient to refer to, and which have supplied us with examples and illustrations. Nevertheless, they are languages which may be more or less unfamiliar to us. It may also be useful to prepare ourselves for three or four more languages. which will have to be introduced for the same purpose. By doing this we shall get our facts, as well as our reasonings; we shall learn (so to say) the handling of our tools, as well as the names of them. The more we know about such tongues as the Gipsy, the Welsh, and the Gaelic, the easier it will be to remember the principles they exhibit. Now, the languages of the whole world amount to some hundreds, of which there is no occasion to make a list. The greater part of them are known only to the missionary and the professed grammarian. It is only a few of them that are of general importance. Of these, what are the languages of which we hear the most in England, and with which an Englishman has most to do? This, though at first sight an easy question, depends a great deal upon circumstances, for its answer. In one part of England we hear more of one language, in another, of another. Then there are certain parts of Great Britain which are Welsh, Scotch, and Irish, rather than truly and properly English. Hence a language that one reader may hear a good deal about may be comparatively unknown to another.

2. *The French.*—Take, for instance, a person living at Dover or Folkestone, with the white and chalky shore of France within sight, with Calais and Boulogne within a few hours' sail, and with steamer after steamer, either making for the harbour or leaving it. Then, add to this the number of Frenchmen that are to be seen in the streets, on the pier, in the inns, and lodging-houses. There is no doubt as to their being foreigners, as to their own language being a foreign one, as to their English, when they speak it, bearing all the signs of a tongue to which they were originally strange. There is the French accent, — and that unmistakably conspicuous in all they say. The foreign language most

known here is the French, all the world over, just as the foreign language best known at Calais and Boulogne is the English.

3. *The German.*—But change the scene from Kent and Sussex to Lincolnshire or Yorkshire; from Dover and Folkestone to Grimsby and Hull. In these last-named ports, though the French is still an important foreign tongue, there are others that are more so—more generally spoken by the foreign crews, and more necessary to the Hull or Grimsby trader. The Dutch is one of these, the German another, the Danish a third, the Swedish a fourth; nay, when we get to the cargoes of hemp, tallow, and linseed, we may be struck with the peculiar sounds of the Russian.

4. *The Welsh.*—Now all these are languages absolutely foreign to the soil of Great Britain, and languages which no Briton or Englishman ever learns naturally, and in the way he learns his own mother-tongue. He may find it, indeed, useful to study them, and having done so, he may speak them to his own satisfaction, and in a manner intelligible to his hearers—but this is not to speak one's mother-tongue.

But let us move westwards to the counties of Hereford, Shropshire, and Cheshire. There is a fresh language that claims our attention here, though not spoken within the borders of the four counties above mentioned. There is the *Welsh.* The chances are that the boys and girls of these parts hear as much about the Welsh as the Dover and Folkestone children hear about the French. They know, at any rate, that if a Welshman talk *his* language, and they (the Englishmen) talk *theirs*, there is no understanding one another. Again, although the Englishman calls himself *English*, the Welshman designates him differently, calling him a *Saeson.* In like manner the Welshman does not call himself by the name which the Englishman gives him (*Welsh*), but by the term *Cymro.* So that the very names by which each denotes the other are strange. The Welshman (as *we* call him) is only Welsh in the eyes of the Englishman, whereas the Englishman is only English in his own; being in those of his neighbour a *Saeson*. Ask one of the peasants of Caernarvonshire or Merionethshire a question in English, and it is highly probable that he will say *Dym Sassenach*. A French would say, *Je n'entends pas*. Both mean the same thing, though in a different manner. *Dym Saesneg* means *No English*, whilst *Je n'entends pas* is *I do not understand*.

5. This much about the Welsh, concerning which there is much more which may be advantageously known. In the first place, we may explain the words *Saeson* and *Welsh*, and show how the two words got the present application. It may be remembered, as a piece of history, that the three nations who are said to have landed from Germany and conquered Britain, under Hengist and Horsa, Ella and Cerdic, and several other redoubtable chieftains, were the Jutes, the Angles, and the *Saxons*. This is not the exact history, but is near enough to explain the term under notice. The ancestors of the Welsh were the ancient Britons, once the occupants of all South Britain—of Lincolnshire and Kent, as truly as of Denbighshire or Cardiganshire. Now, when these were attacked by their enemies from Germany, they made no distinction between the Angles, the Jutes, and the Saxons, but treated them all as one people—just as we did, in the course of time, when, from the particular name *Angle*, we gave the whole island the name of *Angla-land*, the *Land of the Angles*, or *England*. The Britons did the same; except that of the three names they chose the word *Saxon*, instead of *Angle*, a name which *we* allowed to fall into disuse; a name which is now nearly foreign to our language; a name, which, when applied to an *Englishman*, is, nevertheless, a *Welsh* word.

6. As to the words *Welsh* and *Wales*, they are *English*; though, like many others, they are not to be found in the present language. They are common enough, however, in the old English—in the language as it was spoken by Ecbert, and Alfred, and Edward the Confessor, and the other kings before the Norman conquest. In this stage of our tongue the word *wealh* meant *foreigner*, also *slave*, inasmuch as when foreign

countries were conquered, the slavery of their inhabitants too often followed as a matter of course. Of this word *wealh*, the plural number was *wealh-as*, from whence has come the present word *Wales*, which was, originally, the name of the *people* rather than the *country*. However it, eventually, came to mean the *country* instead of the *people*. Meanwhile, the adjective wealh-*isc*, weal-*ish*, wal-*ish*, took form, from which we get the present word wel-*sh*, a word sometimes, but most incorrectly, spelt wel-*ch*. The *sh*, however, is the same as the -*sh* in such words as self-*ish*, &c. This, however, is a remark by the way.

7. *The Cornish.*—In the Welsh, then, we get a fresh language, spoken within and belonging to the British Islands, a language which, at one time, was extended far beyond its present boundaries. So late as the beginning of the last century it was spoken in Cornwall, and called the *Cornish*. Practically, however, the Cornish and Welsh were the same language, though the likeness between them was disguised by the fact of each having certain peculiarities of spelling. Let us, however, designate the two by the general name of *British*.

In the reign of Queen Elizabeth, the people of Devonshire spoke of the *Cornish* as a strange language, just as the present people of Hereford and Cheshire speak of the Welsh. At present, they hear nothing about it, because the last old fishwoman who spoke it has been dead more than sixty years, so that it has become what is called a *dead* language, or a language that no living person speaks as his native mother-tongue. At the same time there are a few Cornish works—they can scarcely be called books—which have come down to us, having been composed when the language was spoken (was *alive* so to say), committed to writing, and, by that means, preserved to the present time. Finally, it should be added, that several words of the old Cornish are to be found in the present provincial dialect of the county of Cornwall, fragments of the original British, and foreigners in the present English.

8. *The Irish Gaelic.*—We are now prepared to leave England, and to cross the channel for Ireland, where

we shall meet with the same kind of phenomena that we met with in Wales. The English will be spoken—but it will be spoken with a remarkable accent, which shows that, in the mouth of the speaker, it is, more or less, a foreign and unfamiliar language. Still it will be spoken—just as it was in Wales. In Wales, however, there was a second language besides. So there is in Ireland. In Wales this language was the Welsh, or British. In Ireland this language is the Gaelic, or Erse. We have seen a specimen of it in the table of numerals at the beginning of the present chapter. The Welsh is not spoken all over Wales; no more is the Gaelic all over Ireland. In Radnorshire there is little but English. In the north of Ireland there is less Gaelic than in the south and west. The country gives us more Welsh than do the towns. The country does the same in Ireland. Vast numbers of Welshmen can speak nothing but English. Vast numbers of Irish know no Gaelic. Nevertheless, in those parts, both of Ireland and Wales, where the English influences are the least powerful, the true, native, mother-tongue of the people—the country-people more especially—is Welsh on the one side, and Gaelic on the other.

9. *The Scotch Gaelic.*—From Wales we went to Cornwall. From Ireland we go to Scotland. In Cornwall we found that the Welsh had *once* been spoken even there. In Scotland we shall find that the Gaelic is spoken at *the present time.* But it is not spoken all over North Britain. You will look for it in vain in the Lothians, in Dumfriesshire, in the parts south of the Forth. On the other hand, you will find it abundantly in Perthshire, in Argyllshire, in the Highlands. Call this the *Scotch Gaelic.*

10. *The Manks.*—Half-way between England and Ireland, and at an equal distance from Scotland, lies the Isle of Man—the kingdom of Man, as its inhabitants call it, with laws, customs, and a parliament of its own, and also with a language of its own. Call this the *Manks.* It is closely allied to the Scotch and Irish Gaelic.

11. So little, then, is the English the only language of

Great Britain, that there are, at least, two others spoken alongside of it—*two others at least.* There is (1) the *Welsh,* and (2) the *Gaelic.* I say "*at least,*" because the Cornish is not counted, both from the fact of its being extinct, and from the fact of its being so nearly akin to the Welsh as to be little more than that language under another name. Neither are the Manks and Scotch Gaelic separated from the Irish.

12. We may say, then, that there are at least three different languages natural to the British Isles—a fact which the natives of the eastern parts—the exclusively English parts—of England sometimes overlook. It is better to bear it in mind; for, although, without doubt, the English is far more important than both the others put together, they still must be taken as we find them—still considered the mother-tongues of so many of our fellow-citizens. A Norfolk clergyman in a Welsh parish soon discovers the importance of the Welsh language, or, at any rate, the inconvenience of his ignorance of it. So do English managers in Welsh mines and on Welsh railways. The same is the case with the Gaelic.

13. *The Norwegian of the Orkney Isles.*—Until the 17th century, *Norwegian* was spoken in a part of Great Britain—a fact well known in the north of Scotland, but unfamiliar to the South Britons, the Welsh, and Irish. How, indeed, should they find it out? It was a fact that lay out of their field of observation. However, no fact is more certain than that as late as the 17th century, Norwegian was spoken in the Orkney Isles, and in the Shetlands. Nor is this strange or unaccountable. When the Danes ravaged England, the Norwegians robbed Scotland. When the Danes were in Lincolnshire and Yorkshire, the Norwegians were in Caithness and Sutherland. Their course, indeed, seems to have been as follows:—From their own country of Norway, they sailed to the opposite parts of Scotland, these being the northernmost districts of our island. So that Orkney and Shetland, Caithness, and Sutherland, became little better than Norwegian settlements. Then they lapped round the western coast, following the line

of the Hebrides until they reached the Isle of Man. This was another of their occupancies. It was also a starting-point for further depredations on the coasts of Ireland, England, and Wales. It is no wonder, then, that Norwegian found its way to Orkney. How came it, however, to continue there so long? Talk ten minutes with a Dane about the north of Scotland, and you will hear the reason. Until late in the 15th century, the Orkney Islands were no English possession at all; but, on the contrary, the property of the Danes, just like the Faröe Isles and Iceland at the present moment. Money, however, was wanted by the King of Denmark, which England lent on the Orkney Isles and Shetland, as a security. In fact, they were *pawned*.

No one, however, hears much of the Norwegian of the British Isles, at the present time, and, perhaps, when it was still spoken as a living language in Orkney, no one heard much about it. It was different, however, a thousand or nine hundred years ago, when Canute was king of the three kingdoms of Denmark, Norway, and England. We heard enough, and more than enough, of the Norwegian then. It was the same as the Danish of the terrible Danes. The language that was spoken in the Orkneys was the language of the great king last named, the very language in which he rebuked his courtiers. It was the language that was spoken in Guthrum's camp when Alfred visited it in the disguise of a harper. It was the ruling language of, at least, five counties, viz., Yorkshire, Lincolnshire, Leicestershire, Nottinghamshire, and Derbyshire. It was, probably, spoken in that portion of Lancashire which is still called West Derby. It was certainly spoken in parts of Westmoreland and Cumberland. On the banks of the river Nene, where it divides the counties of Huntingdon and Northamptonshire, the Danish Norwegian, or Norse (for it is all the same), seems to have been spoken on one side of the river, whilst the English was the language of the other; so that there were two populations within a stone's throw of each other. Without going further in these inquiries, let us simply remember of the Norwegian of the Orkney Isles, that it is now extinct; and that it is the second language in that predicament—the Cornish having been the first.

14. *The Rommany*, or *Gipsy*.—Our list has not yet come to a close; indeed, it contains four more languages, all of which, in some part of Great Britain, to some class or other of Englishmen, either now or formerly, are or have been of interest. One of them is our old friend the Gipsy, which is, to all intents and purposes, a foreign language. There was once a time when no Gipsy had set foot in England, and when no word of the *Rommany* tongue (for Rommany is what the Gipsies call themselves) had ever been heard by an English ear. There was a time, earlier still, when no Gipsy foot had ever pressed the soil of Europe. Their original home was in the East, in India, and it is from India that they have spread over all the countries between the Indus and the Atlantic. They are abundant in Russia, Poland, Bohemia, Hungary, Spain, France, Italy. They are found even in Norway. They have not, however, yet crossed the Atlantic—not wandered so far west as America.

15. *The Hebrew*.—The next language is also of Eastern origin, the language of the Law (but not of the Gospel), the language of the Prophets, the language of the Old Testament altogether. This is the mother-tongue of the Jews of England—the Hebrew. It is the same as that of the Jews of Spain, Poland, and the East. It is the tongue of the Hebrew race, wherever that race may be found. This language, when used in England, is wholly different from the English; and when spoken in Spain, in Poland, or in Germany, it is just as different from the languages of those countries—the Spanish, the Polish, or the German. Its real relations are to the languages of Arabia and Syria. *There*, the English is the foreign tongue. At the same time, it is not so like the forms of speech of these parts as to be other than a separate language—the oldest, and one of the most important, in the world. As time goes on languages change; so that it must not be imagined that the Hebrew of the modern Jew is

the same as the Hebrew of the Old Testament—written so many centuries ago. Nevertheless, it is from that ancient tongue that it is descended, and it is that ancient tongue of which it is the modern representative.

16. *Difference of Alphabets.*—The Hebrew introduces to us a fresh fact. It is one thing to *speak* a language, another to *write* it. Nine-tenths of the languages of the world have never been written at all, being the mother-tongues of rude tribes to whom the use of the alphabet is unknown. Nor is this wonderful. It is no easy thing to invent an alphabet. In the first place we have to discover that a word consists of several simple sounds, combined in a given manner; we have then to separate these simple elementary sounds from each other—to analyze the word (so to say), to take it to pieces. Then we have to invent a sign for these simple sounds, a sign which speaks to the *eye* instead of to the *ear;* a sign that we can *see.* Thus, *man* consists of the three sounds, *m*, *a*, and *n*, which we can separate from each other. We can not only do this, but we can recombine them afresh; M, for instance, appears in a separate form from both the A and N in such words as *meet*, *mix*, &c. &c. A appears separate from the M and N in such words as *ask*, *add*, &c. N appears separate from the M and A in such words as *nod*, *never*, &c. No man can *see* the sound of the first letter in *nod* any more than he can *hear* the form of the letter N. So that speaking and writing address two different senses.

Now, there is no reason that the letters M, N, or A, in the words under notice, should be of the shape they are rather than any other. Why would not such signs as מ, נ. or א, do equally well? Perhaps they might not be so convenient to write. This may or may not be the case. It is clear that if the inventor of an alphabet choose to make a letter of one shape rather than another, he is at liberty to do so. Now, the signs, or letters, are the same in the seven languages we have hitherto noticed: the English, the French, the German, the Welsh, the Gaelic, the Norwegian, and the Gipsy (or the Rommany). They are different in the Hebrew. In other words, the Hebrew alphabet is peculiar; indeed, to go no further than the word MAN, the signs which we have given as imaginary or possible, are *real* ones. In other words, the Hebrew M is מ, the Hebrew A is א, and the Hebrew N is נ, the other letters of the alphabet being equally different from our own. Hence, what we write MAN the Jew would write מאנ. This is what we expect. It is not, hovever, exactly the case. There is another peculiarity of the Hebrew alphabet. It is written from right to left; whereas, we write from left to right, so that the true form of MAN is נאמ.

17. *The Latin.*—There are few schools where there is not something to be said about the *Latin Grammar;* and, even where the Latin Grammar is not taught, occasional reference is made to the Latin language. We cannot open a dictionary without finding that such or such a word is of Latin *origin; i. e. derived,* or *deduced* from the *Latin.* Indeed, out of the last seven words of the sentence just written, four of them are words of this kind, viz., the four words in italics—*Latin, deduced, derived,* and *origin.*

Latin is the name of the language itself, so that there is nothing strange in its being of foreign extraction.

Origin is from the Latin word *origo, origin-is,* which is, itself, from *ori-or, I arise*—the *origin* of a thing being that from which it *arises.*

Deduced is from *de,* meaning *from,* and *duco,* meaning *I lead,* so that *deduced* originally meant *led from.*

Derived is also from *de,* meaning *from;* the latter part of the word coming from *rivus, a river,* or *stream.* One thing proceeding from another may be said to be *drawn off* from it, just as water is drawn off from a spring, channel, or reservoir. This idea gives us the word in question; also *Derivation, Derivational,* and *Derivative.*

The Latin, then, is a language which, for some reason or other, is more or less mixed with our own; so mixed up that when we use such words as *origin, deduce, derive,* &c. we may be talking Latin unconsciously, just as a well-known hero of one of the best French comedies, when he took his first lesson in grammar, and discovered that there were such things as *Poetry* and *Prose*, and that the latter was the ordinary form of speech, was surprised and delighted to hear that he had been speaking *Prose* all his life without knowing it.

This is one fact which gives importance to the Latin language. There is another: at one time it was spoken over a large portion of England. It was the language of the Romans; and as the Romans conquered Britain, the Roman, or Latin, language of the conquerors found its way to the British Isles. Had it not been for the subsequent conquests of the Angles, and (probably) other German tribes, the Latin, or a language descended from it, would be spoken at the present time—just as is the case in Spain, Portugal, France, and Italy; the languages of all of which countries, although known under the several names of Spanish, Portuguese, French, and Italian, are all allied to each other, and all of Latin descent. Indeed, their Latin origin is the reason for their being allied amongst themselves, just as descent from the same grand-parents connects first cousins in the way of ordinary relationship. If this be the case, a knowledge of Latin helps us in the study of French, Italian, Portuguese, and Spanish. Such is actually the case. To learn Latin is to have half learned Italian beforehand.

But this is not the chief reason why the Latin is so important, though it is one of considerable importance. The Romans had the use of the alphabet earlier than any nation of Europe except the Greeks. They were also (as is well known from history) a powerful and civilized people. They were powerful enough to conquer more than half Europe, and civilized enough to improve the condition of the nations whom they reduced. Hence (with the exception of the Greek) the earliest literature of Europe was Latin, Latin being a written language when English, German, &c., were not. Some of the best models of composition are in the Latin language, so are some of the profoundest works in philosophy. Again, as Latin is studied in all the universities of Europe, it is, to a certain extent, a common medium of communication between educated foreigners, inasmuch as a German who knows no French, an Englishman who knows neither French nor German, and an Italian who, perhaps, knows none of the three languages (supposing them all to know Latin), may converse with each other. A generation or two back this application of the Latin language was commoner and of more practical importance than it is now. Thus, when George I., who had all his former life been an elector of Hanover, became King of England, he could speak no English, whilst, very unfortunately, his ministers (with one exception) could speak no German; neither were they very strong in French, which was not so generally used in royal courts as it is at present. The consequence was that Sir Robert Walpole and His Majesty, when they talked together, talked Latin. And this was not very intelligible, because, as the Latin itself is no longer a living tongue, each nation pronounces it according to the pronunciation of its own language. Now different nations pronounce different letters differently, *e. g.*, what an Englishman sounds as *a* (in f*a*te) a Frenchman sounds as *ah* (or the *a* in f*a*ther). The Frenchman too (as do the Germans and others), sounds *i* as *ee*. All this increased the difficulties of our first two Hanoverian sovereigns and their ministers understanding each other.

However, as the study of modern languages has advanced, difficulties of this kind have decreased. In like manner the use of the Latin, as a vehicle of conversation has decreased. Its chief value *now* lies in its literature, and this value is a very high one.

18. *The Greek.*—The Greek language was cultivated earlier than even the Latin, and the models of composition which it supplies are of still higher value than those that give importance to its rival tongue, for such we may deem the language of the great and conquering Romans.

Like the Latin, the Greek has given many words to our language, such as *mathematics*, *physics*, *politics*, *optics*, &c. Thus, *mathematics* comes from *mathematica;* it means *things appertaining to learning*, which comes from *mathema*, *learning*, which comes from *math*, *learn*. When this name came into use, such importance was given to geometry that it passed as *the pre-eminent kind of learning*, and took its name therefrom.

Physics comes from *physica*, meaning *things appertaining to nature*, which comes from *physis*, *nature*.

Politics comes from *politica*, meaning *things appertaining to a polity*, or a *system of government*, which comes from *polis*, *a state*.

Optics comes from *optica*, meaning *things appertaining to sight*, which comes from *opt*, *see*.

Now, these words should tell us something new, or, at any rate, suggest it. If the different departments of human knowledge called Mathematics, Physics, Politics, and Optics, have, each and all, Greek names, what is more likely than that the Greeks, either first or most successfully, cultivated them? We may safely say that these sciences originated in Greece.

The Greeks, like the Hebrews, had a peculiar alphabet. Write *deduco*, *derivo*, *origo*, &c. in Latin, and you write them as they are written here; but write such words as *Mathematica*, *Physica*, *Politica*, or *Optica*, in *Greek*, and you have to use a new series of letters—some of which are *very* like the English, some *rather* like, others different. Thus—

Mathematica in Greek letters is *μαθηματικα*.
Physica ,, ,, ,, *φυσικα*.
Politica ,, ,, ,, *πολιτικα*.
Optica ,, ,, ,, *οπτικα*.

I shall conclude this lesson by giving the numerals in English, Latin, and Greek; the last being given in the same way that we have already given the four words just noticed, viz., in the proper Greek letters and in the English. Out of this the student may make for himself an exercise. Let him work out a Greek alphabet for himself, getting his equivalent to *a* from one word (say the last letter in *εννεα*), his equivalent to *b*, from another (say the second letter in *εβδομα*), and so on as far as the words and his comparisons carry him.

ENGLISH.	LATIN.	1. GREEK.	2.
One.	un-us.	εν-ος	en-os.
Two.	duo.	δυω	duo.
Three.	tres.	τρεις	treis.
Four.	quatuor.	τετταρα	tettara.
Five.	quinque.	πεντε	pente.
Six.	sex.	ἑξ	hex.
Seven.	septem.	ἑπτα	hepta.
Eight.	octo.	οκτω	octo.
Nine.	novem.	εννεα	ennea.
Ten.	decem.	δεκα	*deka.

This is *Exercise* I.

Exercise II.—Repeat, with the Latin, Greek, and English, the comparison which was made with the English, Welsh, Gaelic, and Gipsy.

Exercise III.—The first of the following samples is the Lord's Prayer in the Norwegian of Orkney: the second, the same in one of the provincial dialects of Norway. Work out the parts wherein they are like and unlike each other, and then those wherein they are like or unlike the English.

1.

Far vor i ir i Chimrie; helleur ir i Nam thite; gilla Cofdum thite cumma; veya thine mota vara gort o yurn, sinna gort i Chimrie; gav us da on da dalight Brow vora: forgive uus Sinna vora sin vee firgive Sindara mutha uus; Lyv uus ye in Turntation; min delivera uus fro olt ilt. Amen, on sa meth eth vera.

2.

Faer váar, du sum er i Himlen; Helket vaarde dit namn; til-komme os dit Rike; sje di wöllie her aa Jera, sem den sjer i Himlen; giv os höer Dak waart daklike Brö; og forlaat os vaar Sjula, som vi forlaate vaare Sjuldner; leet os ikkie uti Früstelse; men fräls os fra det one; ty Riket er dit, aa makten, aa Aran i Euikhet.

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* Or *deca.*

LESSON III.

CONSIDERATIONS SUGGESTED BY THE OBSERVATION OF OUR OWN MOTHER-TONGUE.

"In those days also saw I Jews that had married wives of Ashdod, of Ammon and of Moab:

"And their children spake half in the speech of Ashdod, and could not speak in the Jews' language, but according to the language of each people."

1. THE more a student knows of other languages besides his own the better, inasmuch as every fresh form of speech gives him some new fact, of which he soon finds the application. On the other hand, however, there is plenty in his own unassisted mother-tongue that only requires to be made the object of his observation and reflection, in order to give him a fair knowledge of the leading principles of Grammar and Philology. The Greeks, with their influence upon human civilization, achieved their greatest intellectual works by means of an exceedingly small amount of acquired knowledge. In the matter, indeed, of language they knew nothing but their own native form of speech. The Romans, indeed, studied the Greek; but the Greeks studied neither the Roman (or Latin) nor any other foreign tongue. The ancient Persian was, in their time, the more important of what an Athenian might, perhaps, call the *modern languages;* being of much the same political importance as the French is now. Nevertheless, not one Greek out of ten thousand could either read or speak it. Yet it was the Greeks who invented the Science of Grammar. So much, then, may be gleaned in a narrow field, provided that we work it with activity and care. Our own language, if rightly examined, will tell us how forms of speech *change*.

2. Changes in language are of two kinds—changes of *form* and changes of *meaning*. Both can be observed within the domain of the English language. It is scarcely possible to bring twenty persons together from different parts of England, who all speak exactly alike, each giving every word he uses *exactly* the same sense,

and each pronouncing every letter of those same words exactly alike. I do not in this statement allude to cases of stammering, or imperfect pronunciation, nor yet to individual instances of incapacity to pronounce certain sounds; still less am I thinking of children, whose language and pronunciation are still imperfect. There is something to be observed even here; but this is not what I am considering at present. It is scarcely possible, I say, to bring twenty persons from different parts of the country, each giving exactly the same sound and the same sense to the same word. A Londoner sees this if he fall in company with a Yorkshireman, and a Yorkshireman sees it if he talk to a Scotchman. A Scotchman, in like manner, detects an Irishman. And so it is throughout. Now let a company of settlers from Yorkshire, London, Scotland, and Ireland, form a settlement by themselves, they will retain their own form of speech. This, in the course of time, will undergo a change. It will change a little in a single generation, more in two, still more in three, and so on.

3. *Stages of Language.*—The same form of speech, the same language, the same dialect undergoes change as time goes on, and if the change be sufficiently great, and the time sufficiently long, the effects will be considerable. They will first effect a difference of dialect: they then will bring out a new language. At one time —some thousand years ago—the language of England, Holland, Germany, Denmark, Norway, Sweden, and Iceland, was the same. At one time—say a thousand years back—the French, Italian, Spanish, and Portuguese were all one—all Latin. They are now different languages; some exceedingly like, others comparatively unlike each other. Thus the numerals are as follows for the

ENGLISH.	GERMAN.	DANISH.
One.	Ein.	En.
Two.	Zwei.	To.
Three.	Drei.	Tre.
Four.	Vier.	Fire.
Five.	Fünf.	Fem.
Six.	Sechs.	Sex.

ENGLISH.	GERMAN.	DANISH.
Seven.	Sieben.	Syv.
Eight.	Acht.	Otte.
Nine.	Neun.	Ni.
Ten.	Zehen.	Ti.

All like, yet all different. Then they are in—

ENGLISH.	LATIN.	FRENCH.
One.	Unus.	Un.
Two.	Duo.	Deux.
Three.	Tres.	Trois.
Four.	Quatuor.	Quatre.
Five.	Quinque.	Cinq.
Six.	Sex.	Six.
Seven.	Septem.	Sept.
Eight.	Octo.	Huit.
Nine.	Novem.	Neuf.
Ten.	Decem.	Dix.

The Spanish, &c., being, more or less, like and unlike. It is, in short, the recurrence of the old fact—likeness and difference, difference and likeness.

4. *Causes of Change.*—To return, however, to our own dialects, and to the facts that our own language supplies us with. We may easily find upon a little consideration, that one idea is often expressed by two or more words. Thus instead of *two*, we may say *pair*, *couple*, *brace*. Suppose that one body of English settlers fixing themselves elsewhere, prefers the use of one of the last-named words instead of the ordinary number *two*—and suppose, for instance, they talk so much of *pairs* or *couples*, as to let the word *two* drop out of their language; there is a change effected to the extent of one word at least.

Then let some new object present itself, a new tree, a new animal, a new instrument, a new article of commerce; a name is wanted for this. This effects another change.

Then let some old and hitherto familiar object be no longer old and familiar. A word drops out of the language.

All nations do not express the same idea in the same way, even when they can. *We* English have the words *hand* and *shoe*, and if we chose we might combine them. It is pretty certain that men wore *shoes* before they wore *gloves*. It is absolutely certain that they had *hands* before they had *gloves*. However, in the course of time *gloves* came to be used. A name is wanted. Why not call them *handshoes?* We do *not* so call them; the Germans *do* so call them. The German for *glove* is *handschuh*. The use of this compound effects a difference. It gives the Germans a new word; it also makes the English word *glove* unnecessary.

Again, when one nation settles in the country of the other, it rarely happens that the original tongue is utterly lost. It generally supplies some words to the new one. Even in the English of the United States we find such words as *wigwam* and *squaw*. Now these are Indian terms; terms belonging to the original languages of the country, terms in use before Columbus was born, and at a time when no white man had trodden the soil of the New World.

Then there are new words introduced by commerce, literature, science, and the like. Such words were the ones from the Latin and Greek of our last lesson. Such words are *shawl*, *tea*, *coffee*, &c., &c., words which had no existence until we came to have dealings, either direct or indirect, with India, China, and Arabia.

These are a few samples out of many of the way in which languages may change.

The following extracts from an old poem of the thirteenth century give us, not only a specimen of the Old English, but of the Old English in *two dialects*:—

1.	2.
Bladud hafde ene sune,	Bladud hadde one sone,
Leir was ihaten;	Leir was ihote;
Efter his fader daie;	After his fader he held þis lond,
He heold þis drihlice lond,	In his owene hond.
Somed an his live,	Ilaste his lif-dages,
Sixti winter.	Sixti winter.
He makade ane riche burn,	He makade on riche borh,
Þurh radfulle his crafte,	Þorh wisemenne reade,
And he heo lette nemnen,	And hine lette nemni,

1.	2.
Efter him seolvan;	After him seolve;
Kaer-Leir hehte þe burh.	Kair-Leir hehte þe borh.
Leof heo wes þan kinge,	Leof he was þan kinge;
þa we, an ure leod-quide,	þe we, on ure speche,
Leir-chestre clepiad,	Leþ-chestre cleopieþ,
Geare a þan holde dawon.	In þan eolde daiye.

In modern English.

1.	2.
Bladud had a son,	Bladud had a son
Lear was called;	Lear was called;
After his father's days	After his father he held the land
He held his liege land	In his own hand
Together on (through) his life	Through his life-days
Sixty winters.	Sixty winters.
He made a rich borough	He made a rich borough
Through his wise craft	Through wise men's counsel
And he it let name	And he let it name
After himself.	After himself.
Caer Lear was called the burgh	Caer Lear was called the borough.
Dear was it to the king.	Dear was it to the king.
Which we on our language	Which we, on our speech,
Leicester call	Leicester call
Of yore on the old days.	In the old days.

Hight meant ***called*** so late as the time of Charles II. Dryden uses it—Barbican it ***hight***, ***i. e.***, it was ***called*** (or ***bore the name of***) Barbican.—R. G. LATHAM.

Specimen of the Dorsetshire Dialect.

THE HARNET AND THE BITTLE.

A Harnet zet in a hollow tree,—
A proper spiteful twoad was he,—
And a merrily zung while a did zet,
His stinge as zharp as a baganet,
"Oh, who 's zo bowld and vierce as I,—
I vears not bee, nor wapse, nor vly?"
Chorus—Oh, who 's zo bowld, &c.

A Bittle up thuck tree did clim',
And scarnvully did luk at him,
Zays he, "Zur Harnet, who giv' thee
A right to zet in thuck there tree?
Although you zengs so nation vine,
I tell 'e it 's a house o' mine."
Chorus—Although you zengs, &c.

The Harnet's conscience velt a twinge,
But growin' bowld wi' his long stinge,
Zays he, "Possession 's the best law,
Zo here thee shasn't put a claw.
Be off, and leave the tree to me:
The Mixen's good enough vor thee!"
Chorus—Be off, and leave, &c.

Just then a Yuccle passin' by,
Was axed by them their cause to try.
"Ha! ha! it 's very plain," zays he,
"They' ll make a vamous nunch vor me!".
His bill was zharp, his stomach lear,
Zo up a snapped the caddlin pair.
Chorus—His bill was zharp, &c.

MORAL.

All you as be to law inclined,
This leetle story bear in mind;
For if to law you ever gwo,
You 'll vind they 'll allus zarve 'e zo;
You 'll meet the vate o' these 'ere two;
They 'll take your cwoat and carcass too!
Chorus—You 'll meet the vate, &c.

Natural History.

BY ROBERT PATTERSON.

LESSON I.

ON THE USES OF ANIMALS TO MAN.

"And God said, Let us make man in our image, after our likeness; and let them have dominion over the fish of the sea, and over the fowl of the air, and over the cattle, and over all the earth, and over every creeping thing that creepeth upon the earth."

1. The words of Adam Smith, in his "Wealth of Nations," form an appropriate introduction to this subject, and suggest two of its most important divisions:—

"In that rude state of society, in which there is no division of labour, in which exchanges are seldom made, and in which every man provides everything for himself, it is not necessary that any stock should be accumulated or stored up beforehand in order to carry on the business of the society. Every man endeavours to supply by his own industry his own occasional wants as they occur. When he is hungry, he goes to the forest to hunt: when his coat is worn out, he clothes himself with the skin of the first large animal he kills."

The state of society now, over a great part of the world, is widely different from that to which Smith refers; yet animals still continue to supply to man a large portion both of his food and of his raiment. These "uses of animals to man" are of primary importance, and have continued throughout all the phases of human civilization, though varied in each country according to physical and social conditions. They therefore form the first subjects for consideration.

2. FOOD.—Sir Robert Schomburgk, in his "Description of British Guiana," enumerates the following animals as affording to man "a wholesome and delicate food." "The tapir or maissuri, the capibara or waterhaas, the labba, the aguti, the acuchi, the cairuni or wild-hog, the peccari or Mexican hog, and deer of different species; other animals are the ant-eater, armadillo, sloth, otters, several species of polecats and opossums. Numerous herds and varieties of monkeys people the otherwise solitary forest, and serve as food to the natives. The manati, lamantine, or sea-cow, is from time to time met with in the larger rivers; its flesh is white and delicate, and has been compared in taste to veal."

Birds, reptiles, and fishes are also mentioned in the same work as furnishing food to man; but even without these we are struck with the variety of the mammiferous animals which contribute in that one country to human sustenance. How vastly would the list be extended, if it embraced those portions of the earth's surface, where favourable conditions of soil and climate supply food to other races of animals, which become in their turn tributaries to the great family of man!

3. Let me now, by "my so potent art," transport the reader from the teeming life of tropical countries to "thrilling regions of thick-ribbed ice," where the reindeer furnishes to the Laplander flesh and milk, food and

clothing, or the seal supplies to the Esquimaux, not only nourishment, but light and warmth. In our own country, surrounded as we are, not only with abundance, but with variety of food, it is difficult for us to realise the importance of even one species of animal in regions which are differently circumstanced. As we only estimate aright the blessing of health when sickness has laid her hand upon us, so we can only appreciate the value of the seal to the Esquimaux when we look upon him as deprived for a time of his customary supply. This has been strikingly exemplified in one of the scenes brought before us in the simple narrative given in "Parry's Second Voyage" to which the reader is referred.

4. Perhaps there is no better way of forming a correct idea of the importance of animals as food to man than to direct our attention to two or three of the best known and most abundant of the ruminating animals, such as the buffalo, the ox, and the sheep. The flesh of the buffalo, or bison of North America, constitutes for the greater part of the year the food of several of the Indian tribes, whose numbers are variously estimated at from seventy to one hundred thousand individuals. The tongue, the hump, and the marrow of the shank-bones are considered the choicest parts. So juicy and delicious is the flesh of the cow buffalo, that hunters prefer it to any beef. Yet though the Indians on the prairies are well aware of the value of these animals, and in fact are to a great extent dependent on them for subsistence, they most wantonly destroy them in such numbers that not more than one out of every twenty individuals slain is actually consumed as food. The hump and perhaps the tongue are taken, the skin is stripped off, and the remainder of the carcase is left unregarded on the plain. The number of buffaloes annually killed, to furnish food for perhaps eight months in the year, to seventy or one hundred thousand people must needs be considerable; but if the wanton destruction of them be such as has been stated, then twenty times that number must be regarded as actually slain by man. An opinion prevails, perhaps not unjustly, that those mighty herds, which at times darken the prairies, are gradually becoming le

numerous, while, at the same time, their range is more circumscribed.

5. Every one in these kingdoms is aware that the ox and the sheep furnish the larger portion of the flesh meat consumed; but comparatively few have ever tried to form a just idea of the actual number of these animals annually killed for our markets. On this point we are not left altogether without some guide, for a correct record has been kept of the numbers annually sold in Smithfield market, London. This is given for many years back in M'Culloch's "Commercial Dictionary;" but the average of each year for the three years ending 31st December, 1852, as there published, will be sufficient for our present purpose. The numbers stand thus:—

Cattle	243,411
Sheep and lambs .	1,569,520
Calves	33,192

If such be the numbers sold in Smithfield in the course of a single year, how vast must be the entire number annually consumed as food in these kingdoms!

6. In parts of South America, where cattle are abundant, there is not only a great annual consumption, but a great annual waste of them; and the Guachos, or natives of the Pampas, live exclusively on beef for months together.

Mr. Darwin, in speaking of a different part of the same continent, thus introduces to our notice another animal, which in these countries we are not in the habit of regarding as an article of food:—

"We were delayed crossing in the canoe, by some immense troops of mares, which were swimming the river in order to follow a division of troops into the interior. A more ludicrous spectacle I never beheld, than the hundreds and hundreds of heads all directed one way, with pointed ears, and distended, snorting nostrils, appearing just above the water, like a great shoal of some amphibious animals. Mares' flesh is the only food which the soldiers have when on an expedition. This gives them great facility of movement; for the distance to which horses can be driven over these plains is quite surprising; I have been assured that an unloaded horse can travel a hundred miles a day for many days successively."

The excellent naturalist, whose "Journal" has just been quoted tells us in another part that he found the dish on which he was supping on one occasion was puma; and he adds, "the meat is very white, and remarkably like veal in taste."

7. "The traveller Bell observed whole rows of badgers hung up for sale in China, just as rabbits are displayed in the British markets; and those who have partaken of the meat, especially of the hams of the European badger, report that it is excellent. Major Lloyd, in his Field Sports of the North of Europe, remarks, 'Its flesh is very eatable when parboiled in bay-seed water, or still better in salt water, and afterwards roasted and left to cool, and used for luncheons; it has then been regarded by epicures as a real delicacy; but it must be the flesh of very young badgers.' Of an allied species, the canajou of North America, the Hon. C. A. Murray relates in his Travels, 'We made our soup, and I boiled my badger; his own fat was all the basting he required; and when he was served up, we all agreed that we had never eaten better meat: it had but one fault, being so exceedingly fat, that it surpassed, in that respect, any pig or other animal that I ever saw. Fortunately it was young, or it might not have been so tender as it actually proved.'

"Mr. Jerdan gives his personal testimony that the flesh of the hedgehog is excellent; and a mole-catcher relates that he was in the habit of eating the moles he caught, and said that if folks generally knew how good they were, but few would fall to his share. The armadilloes are exceedingly foul feeders, yet all who have partaken of their flesh, agree, that one 'roasted in its own shell,' is most delicate eating."

8. If we turn from mammiferous animals to birds, and regard them, at present, merely as food for man, the range of subject, even when thus limited, embraces every country on the globe, and every isle that gems t'

ocean. To attempt any enumeration here is impossible. Each reader must draw his own conclusions, mentally summoning before him the millions of plumed creatures, and as they come to "do his spiriting gently," ask them of their habits and their homes. Whether constantly resident in one locality, or acting under the mysterious impulse of migration, they minister to the wants of man. The picture of the feathered creation, commenced by the poet, may be enlarged and completed by the reader—

————————" the eagle and the stork
On cliffs and cedar-tops their eyries build:
Part loosely wing the region; part, more wise,
In common, ranged in figure, wedge their way,
Intelligent of seasons, and set forth
Their aery caravan, high over seas
Flying, and over lands, with mutual wing
Easing their flight; so steers the prudent crane
Her annual voyage, borne on winds; the air
Floats as they pass, fann'd with unnumber'd plumes:
From branch to branch the smaller birds with songs
Solaced the woods, and spread their painted wings....
Others, on silver lakes and rivers, bathed
Their downy breast; the swan with arched neck,
Between her white wings mantling proudly, rows
Her state with oary feet; yet oft they quit
The dank, and, rising on stiff pennons, tower
The mid aerial sky."—MILTON.

9. Fish would appear to have constituted a portion of the food of man from a very early period. The use of certain kinds is sanctioned in the Mosaic dispensation; and 1,500 years later, we learn from the sacred volume, that they were in common use as food, and were associated with the miraculous events which have given to the sea of Galilee, and the adjacent shores, an interest so peculiarly their own. The writings of Aristotle, the great father of Natural History, have given us minute descriptions of species, which may still be recognised in the Ægean Sea, and which continue to be sought for, as nutritive and delicious food. We know that certain kinds of fish were in high repute among the Romans, and that they even constructed ponds for the due tending and feeding of the kinds most prized at their luxurious feasts. At the present day, among the rudest nations of the earth, devices are adopted for the capture of fish;

and among civilised communities, accustomed to maritime pursuits, the quantity annually taken is so great as not only to furnish a plentiful supply of food for home use, but even to become of commercial importance, as will more particularly be referred to hereafter.

10. One or two facts, to show the vast numbers of fishes taken in different localities, may be mentioned in this place. The river Volga, especially near its mouth, is the great scene of the sturgeon fishery. Fifteen thousand sturgeons are said to be sometimes taken in one day with the hook, at the station of Sallian, on the Persian coast; and upwards of 700,000 were taken, in the year 1829, in the Russian dominions, off the coast of the Caspian.

On our own shores, according to Parliamentary returns, the number of barrels of herrings cured, in 1830, was 329,557. In 1840, it was 406,379. In 1850, it amounted to 507,024. This return does not take any notice of the vast quantities used in their fresh state: could this be ascertained and added to the aggregate as above given, how vast would be the result!

Though it is unnecessary to pursue this part of the subject further, a fact may be stated relative to another of our native fishes, the pilchard. "An instance," says Mr. Yarrell, "has been known, where ten thousand hogsheads have been taken on shore, in one port, in a single day; thus providing the enormous multitude of twenty-five millions of living creatures, drawn at once from the ocean, for human sustenance."

11. Among reptiles used as food for man, every reader will call to mind the turtle, the frog, and some species of lizards. Humboldt states that, in intertropical South America, all lizards which inhabit dry regions are esteemed as delicacies for the table. Soft-bodied animals, constituting the class *Mollusca*, furnish annually a large supply of food to man. Round our own shores, "shell-fish," as they are commonly, though not very correctly called, are generally collected, the kind in each locality varying according to the nature of the coast and the sea-bottom. Whelks, periwinkles, limpets, cockles, mussels, scallops, are used in quantities, which may b

estimated by tons and by hundreds of tons; while the more aristocratic oyster is everywhere regarded with complacency, and takes place in various forms among the favourite dainties of the table. In other countries land-snails are in good repute, and are regularly fed and fattened, as in the time of the Romans, for table use. In tropical seas, some of the "shell-fish" attain a great size; one species (*Tridacna gigas*) has been known to measure above two and a half feet, in the longest diameter of the shell, and contains of course a quantity of food proportionally large. A peculiar interest, however, attaches to some of those mentioned by classic writers, and to none so much as to the different species of cuttle-fishes, which, though not valued on our coasts, are regularly sought for in other seas, and publicly exposed for sale in the markets.

As in ancient times, these mollusks constitute now, on the shores of the Ægean, a valuable part of the food of the poor by whom they were chiefly used. Hence the imprecation of the Chorus, who, calling down upon their victim the extremity of ill-fortune, desired that he might be reduced to a single cuttle-fish, and that a dog might come and snatch this last poor morsel from him, would be as well appreciated in a modern Greek coffee-house, as among the original admirers of Aristophanes. "The Romans, if we may judge from the culinary receipts of Apicius, regarded a cooked cuttle-fish with more respect. We can ourselves," says Professor E. Forbes, "bear testimony to its excellence. When well beaten, to render the flesh tender, before being dressed, and then cut up into morsels, and served in a savoury brown stew, it makes a dish by no means to be despised, excellent in both substance and flavour. A modern Lycian dinner, in which stewed cuttle-fish formed the first, and roast porcupine the second course, would scarcely fail to be relished by an unprejudiced epicure in search of novelty."

12. Another great division of the animal kingdom, supplies the crab and the lobster, the prawn and the shrimp, with many other creatures allied to them in structure and habits. In the southern part of the United States,

one species of crab is particularly valued just after having cast its shell, and before the new one has become hard. It is thus referred to in "Hochelaga:"—"Among the delicacies of the sea, the soft crab is in great request: he is much like ours in shape, but wears only a silken doublet instead of a coat of mail, and consequently can be carved and eaten, without the trouble of undressing him. It is, however, only at certain seasons of the year that his costume is so suitable."

This crab might seem sufficient to tempt an epicure: another jointed or articulated animal is to our ideas the very reverse of tempting, yet so capricious is human taste, that Indian children have been seen, by Humboldt, "to draw out from the earth and eat millepedes or scolopendras, eighteen inches long, and seven lines broad." Many insects, properly so called, are used in their different states as food by man. The grub of the palm weevil has long been in request in both the Indies, and, when roasted, is considered very delicious. So also is the grub of a species of ceramboyx, which is eaten at Surinam, in America, and in the West Indies. The locust tribe, as they are the greatest destroyers of food, furnish in return a considerable supply of it to many nations. They are ground by the Arabs, made into cakes, and baked like bread; they are also boiled and then stewed with butter into a kind of fricassee. Sparman informs us that "the Hottentots are highly rejoiced at the arrival of the locusts in their country, although they destroy all its verdure, eating them in such quantities as to get visibly fatter than before, and making of their eggs a brown or coffee-coloured soup." Clenard, in his letters quoted by Bochart, says that "they bring waggon-loads of locusts to Fez, as a usual article of food."

13. Perhaps no insects have been more celebrated than the cicadas: the ode, addressed to one by Anacreon, would of itself be sufficient to insure for it an immortality of fame. They belong to the tribe *Tettigonia;* and from the time of Homer, who compares the garrulity of age to the chirping of these insects, they have been

celebrated by the poets. It is a curious fact, that the polished Greeks nevertheless did not hesitate to *eat* them, and we are assured by Aristotle they were considered very delicious. These brief notices of edible insects may be concluded by a reference to the termites or white ants. The Africans parch them in iron pots over a gentle fire, and then eat them by handfuls, as we do comfits. Smeathman says, he has several times eaten them, dressed in this way, and thought them delicate, nourishing, and wholesome, resembling in taste sugared cream or sweet almond paste.

It might seem an oversight if, in connexion with insects, no reference to honey as an article of food should be made. But it is so well known from remote antiquity, and used by so many nations, that the mere mention of it is sufficient. The word now by common consent implies what is sweetest and most delicious: earth has no product "sweeter than honey and the honeycomb."

14. It is time to bring this part of the subject to a close, and therefore only two more articles of food shall be mentioned. They both are derived from the lowest of the four great groups, those known to naturalists as the rayed or radiated animals. The first of these is furnished by the sea-urchins, which in the Ægean Sea and in many other parts of the world are in much request. The ovaries are the parts which are eaten. The second is a creature belonging to the family of "sea-cucumbers" (*Holothuridæ*), the sea-slug or bêche de mer. This, when smoked and dried, is sent, under the name of trepang, in shiploads, from Borneo, Singapore, and other places to China, to be used in the preparation of soups. So great is the quantity consumed in this way, that, according to M'Culloch, the number of hundredweights annually shipped from Macassar alone exceeds eight thousand. The Chinese gourmands have reason to rejoice at the acquisition of another delicacy, the edible birds' nests, which are extensively used for soup. Though formed by birds, the material itself is mainly derived from the vegetable kingdom, being one of the

algæ or sea-weeds, resembling the Carrageen moss of the Irish seas. It has been estimated that so much as 300,000*l.* is annually paid for these nests by the Chinese trading in the Indian Archipelago.

LESSON II.

HUNTING, RAIMENT, DOMESTIC USE, AND ORNAMENT.

1. There are several animals that have been trained by man to aid in the capture of others; the dog, the hunting-leopard, and the falcon, will readily suggest themselves as examples. Cormorants were formerly taught in these countries to catch and bring fish to their masters, and are said to be so employed by the Chinese at the present time. The parrot-fish of the Ladrone islands is trained to act as a decoy, and tempt his unsuspecting companions into the net of the fisherman. The natives of the Nicobar group avail themselves of the remora to capture the large turtles which are seen at times sleeping on the surface of the water. It must be remembered that the remora has a very remarkable sucker on the top of its head, by means of which it can attach itself firmly to the lower surface of any floating body. The fisherman has in his boat a tub containing some of these fishes. To the tail of each is a ring, to which a cord can be attached. When the time for action comes, one of these corded remoras is put quietly overboard, swims to the unsuspecting turtle, and attaches itself firmly to the "plastron," or lower shell. When this has been effected, the fisherman hauls in his line; and soon the turtle is a prisoner, lying on its back in the bottom of the boat, while the remora is again in the tub with its companions.

Bishop Heber has, in his "Journal," a passage connected with this part of the subject, which I cannot resist the temptation of quoting:—

"We passed, to my surprise, a row of no less than nine or ten large and beautiful otters, tethered with straw collars and long strings to bamboo stakes on the bank. Some were swimming about at the full extent of their strings, or lying half in and half out of the water; others were rolling themselves in the sun on the sandbanks, uttering a shrill, whistling noise, as if in play. I was told that most of the fishermen in this neighbourhood kept one or more of these animals, who were almost as tame as dogs, and of great use in fishing, sometimes driving the shoals into the nets, sometimes bringing out the larger fish with their teeth. I was much pleased and interested in the sight. It has always been a fancy of mine, that the poor creatures whom we waste and persecute to death for no cause, but the gratification of our cruelty, might, by reasonable treatment, be made the sources of abundant amusement and advantage to us."

2. Among the books which, in my childhood, imparted instruction through the medium of the eye, I recollect one, in which was the picture of a Laplander clad in reindeer-skin, and with a reindeer harnessed to his sledge. There was another of a native of Kamtchatka, in a sledge drawn by dogs, and comfortably enveloped in what I was told represented the skin of a bear; and a third picture, much grander than either of those, of a Chinese mandarin, arrayed in silk, of colours so bright, as to be quite enchanting. If the reader would but conceive three such figures, and add that of a Tartar in his sheep-skin dress; a pair of Esquimaux in their seal-skin costume, as depicted by Captain Sir Edward Parry; and an Indian chief, in his buffalo robes,—he would have before him materials tolerably suggestive of the uses of animals to man, with regard to raiment.

3. But the multiplied wants of civilized life demand that the raw materials furnished by several animals should be subjected to a variety of processes, and thus prepared for being converted into fabrics of different kinds, or into preparations, bearing new names, and possessed of new qualities.

To some of those, forming part of the Great Exhibition of 1851, a brief reference may now be made; and first in point of importance is the wool of the varieties of the domestic sheep.

4. Wool.—" If," says Professor Owen, " the test of the value of a domestic animal be the numbers on the

preservation of which human care is bestowed, and on the extent of the habitable globe over which mankind has diffused the species, then the sheep takes the first rank.

"The most ancient records of our race, both sacred and profane, tell us of the sheep as already an animal domesticated for the food and clothing of man; and it is a significant fact, that both the Scythians of the old elevated plains of Minor Asia — who, according to Herodotus, obtained felt, and, according to Strabo, food from the flocks, and the patriarchal Hebrew shepherds of the plains of Mesopotamia—the earliest instances of pastoral life—dwelt in that part of the earth where the wild argali (*Ovis Ammon*) still exists in greatest numbers.

"Wool is a peculiar modification of hair, presenting, when viewed under the microscope, fine transverse, or oblique lines, from 2,000 to 4,000 in the extent of an inch, indicative of an imbricated, scaly surface, on which, and on its curved or twisted form, depends its remarkable felting property, and its consequent value in manufactures.

"The first importations of wool from New South Wales into England, in 1807, was 245 lbs. In the year 1848, the quantity imported from New South Wales alone amounted to 23,000,000 lbs., valued at more than 1,200,000*l.*"

For use in mixed woven fabrics, alpaca and mohair are extensively imported into England. "The former is the wool or hair of an animal of the llama tribe from Peru; the latter that of a goat peculiar to Asia Minor." The imports of alpaca wool, from 1846 to 1850, were 20,000 bales per annum; of mohair, in 1850, 12,884 bales.

5. SILK.—The most valuable kind of silk, and that which is the subject of the most extensive and painstaking culture, is the secretion of the larva of a species of moth, indigenous to China, called, *par excellence*, the "silk-moth," and, by entomologists, *Bombyx mori*, from its native and favourite food, the leaves of the mulberry trees. The species was first introduced into Europe in the reign of the Emperor Justinian, by two Nestorian monks, who had travelled in China, and succeeded in bringing a quantity of eggs, secured in a hollow

cane, to Constantinople, where they were hatched, and the larvæ fed and reared on the leaves of the white mulberry. The breeding of silkworms in Europe was confined for six centuries to the Greeks of the Lower Empire. In the twelfth century the rearing of silkworms and the manufacture of silk were introduced into Sicily; in the thirteenth century into Italy, whence this important branch of industry has been successively introduced into Spain, France, England, and most of the colonies with a suitable climate."

For centuries back silk has been sò abundant in China, that it has formed the dress, not only of the mandarins, and of persons in easy circumstances, but even the soldiers have been clad with this material, elsewhere considered so valuable.

6. Skins and Furs.—"The temperate and tropical countries supply the peculiar descriptions of hides and skins which are best adapted for leather, while the northern and Arctic regions abound in races of beautiful animals, which are thickly covered with fine hair or fur, whose skins are extremely valuable as articles of clothing.

'The fur that warms a monarch warm'd a bear.'

"The estimated number of hides, skins, and furs imported into Great Britain annually is about 11,000,000, of which 5,000,000 are applicable for furs, and 6,000,000 are adapted for various descriptions of leather."

We read those figures, but we are unable to realize in our minds the numbers they are intended to express. In the imports of wool, the quantity recorded is not equivalent to the number of animals slain. But here it is different; each unit in the vast sum indicates that an animal has died. Confining ourselves to two or three animals, let us see what part they play in these results. In Italy, Spain, and the south of France, it is the custom to kill the lamb at a much earlier period of its growth than in England; the skin is, in consequence, smaller and finer, and is used as a substitute for kid. About 1,400,000 lamb-skins are annually imported for this purpose. We read that 593,000 seal-skins are imported into England annnally, and 15,000 more to be used as furs. A large proportion of these are again exported. But this does not affect the startling fact that above 600,000 are annually slaughtered to supply the skins required in Britain for use and export. What a long range of ice-bound shores would be needed to contain that multitude! Yet those who have been engaged in their capture affirm, that all those annually taken seem not sensibly to diminish the mass. The squirrel, that agile and attractive little animal, abounds in Siberia and the north of Europe. It is said that 15,000,000 are every year captured in Russia, our supply from thence exceeding 3,000,000 annually. Comment upon these numbers is superfluous.

Travellers from these kingdoms, when visiting the countries from which our supply of skins and hides is derived, are much struck with the fact, that animals which we would consider valuable are killed merely for the sake of their skins. Mr. Darwin mentions that at an "estancia" (station, or stopping-place), near Las Vacas (Banda Oriental), "large numbers of mares are weekly slaughtered for the sake of their hides, although worth only five paper dollars, or about half-a-crown a-piece. It seems at first strange," he adds, "that it can answer to kill mares for such a trifle; but as it is thought ridiculous in this country ever to break in or ride a mare, they are of no value, except for breeding."

7. Domestic Use.—Those who are blessed with affluence, and "fare sumptuously every day," derive, not only a larger portion of their food and raiment from the animal kingdom, but are surrounded by a number of little luxuries, comforts, or conveniences, regarded so much as matters of course, that the mind does not, but on rare occasions, revert to their origin. The couch on which the wealthy man reposes may have not only its fine blankets, but its feather bed, its hair mattress, its eider-down pillows, and its silken or damask curtains; hair and bristles, manufactured into brushes, are on his toilet table, with combs of horn, or ivory, or tortoiseshell; and oil and tallow, transformed into perfumery and soaps, wait his requirements. Does he

walk—his umbrella combines in itself three animal products, silk, ivory, and whalebone. Does he ride—the whip and the saddlery are memorials of a similar origin. Does he write—the ivory paper-cutter on his desk, the penknife, with its handle of horn or antler, mother-of-pearl or tortoiseshell; nay, the very quills, if quills he uses, speak of animals living widely apart, and under different conditions. Should sickness come—and it comes to all—the blistering fly and the leech place their powers at the service of the physician; sponges from the sunny Ægean are available, and spermaceti from the Arctic circle, offers its healing powers. Musk, the peculiar secretion of the musk-deer, must be mentioned in any notice, however slight, of animals in connection with *materia medica;* and many a father who has seen the sunken cheeks of his child restored to their former plumpness, by the use of "cod-liver oil," would justly censure the author by whom such a restorative was passed by without notice.

Many of those articles meet our eyes in quantities so small, that we are not aware of their importance. Some particulars on this head may not, therefore, be unacceptable.

8. HORN is extensively used for all the purposes of tortoiseshell, because of its greater cheapness. It is manufactured also into buttons, knife-handles, drinking-cups, powder-flasks, "leaves" or sides of lanterns, and knobs. Among the imports into Liverpool in 1850 were the following:—

	Tons.
Deer horns	280
Buffalo horns . . .	200
Buffalo tips	120
Ox and cow horns . .	700

9. IVORY.—Among the variety of purposes to which ivory is applied, the two consuming the largest quantity of material are the manufacture of combs and of handles for cutlery. According to M'Culloch, the yearly imports of 1840 and 1841 may be taken at 10,372 tusks—a fact which supposes the destruction of 5,186 male elephants. A pair of tusks, obtained from an animal

killed at Lake Agami, in South Africa, is deserving of mention, because of their great size. The pair weighed 325 lbs, and each tusk measured 8 feet 6 inches in length, and 22 inches in basal circumference.

10. TALLOW.—"About a million and a half cwts. of tallow, and 20,000 tons of whale oil and spermaceti," are annually imported into Britain. "In no country in the world is the manufacture of soap carried on to so large an extent." "In Great Britain alone, the production amounted in the year 1850, to 204,410,826 lbs. Of this quantity 12,555,493 lbs. were exported to foreign parts. The total quantity consumed in Great Britain, therefore, amounted to 191,855,333 lbs. Of this quantity 22,858,382 lbs. were used by manufacturers.

11. From the figures now given relating to horns, ivory, and tallow, it is obvious that they form the raw materials of extensive manufactures. For many other purposes in manufactures animal products are available. Glue and isinglass are so well known, they only require to be named as illustrations. The beautiful red dye, "cochineal," is procured from the dried body of a little insect (*Coccus cacti*). This now takes the place of the celebrated Tyrian purple, supplied to kings and rulers, at the time when the "merchants" of Tyre were "princes," "and its traffickers the honourable of the earth." It was derived from a marine animal, a species of mollusk, still living on the shores in the vicinity of that ancient city, and known to naturalists as the *Murex trunculus*.

12. ORNAMENTS.—Some of the animal substances already mentioned may in some of their various applications be regarded as supplying articles of ornament. Ivory, for example, is converted into innumerable little articles, not of utility, strictly so called, but of ornament or luxury; and fur, when used as a trimming for vestments, may be included in the same category. There are, however, other animal products or substances used as ornaments only. Thus, ladies in China embroider their dresses with the elytra or wing-covers of a brilliant species of beetle; in Chili and Brazil they form splendid necklaces of the golden *Chrysomelæ*

and *Curculiones;* and in India they have recourse to fire-flies, which they enclose in gauze, and use as ornaments for their hair when they take their evening walks. Shells, from their variety both of form and colour, have been prized as ornaments by uncivilized tribes, and fashioned into decorations for the person, or for certain portions of the costume. Cameo shells form articles of great beauty, which the cultivated eye of taste may with pleasure contemplate. Nacre, or mother-of-pearl, must not remain unmentioned; but pearls, especially those from the pearl oyster of the Indian seas (*Meleagrina margaritifera*), are those which in all ages have borne the highest pecuniary value. Eighteen hundred years have passed since the memorable words were written, telling us of the merchant-man, "who, when he had found one pearl of great price, went and sold all that he had, and bought it."

13. Feathers are however the ornaments most used, and most accessible. Few can buy pearls, but nearly all who wish for them can purchase feathers; so great is the variety in their value. They nod on the casque of the soldier, they wave on the head of the ball-room beauty, they form in some instances the symbol of rank, and among savage tribes, they become a simple and graceful decoration:—

> "Then came a youth from Georgia's shore—
> A military casque he wore,
> With splendid feathers drest;
> He bought them from the Cherokees;
> The feathers nodded in the breeze,
> And made a gallant crest."

The kinds most in request, are those of the ostrich, the marabout stork, the rhea or American ostrich, the emu, the osprey, the egrette, the heron, the birds of Paradise, Argus pheasant, ibis, eagle, &c.

The feathers of the ostrich have been used in all ages as ornaments for the head. They formed the plumes of knights' helmets, and were very much used by our nobility in the reign of Henry VIII., who himself wore one on state occasions. In their natural state they are still worn by the natives of the Cape of Good Hope, where it is not uncommon to see a waggoner's hat ornamented with them.

Next to the feathers of the ostrich in value are those of the marabout stork, of which there are two kinds, white and grey. The white kind have at times been so scarce as to be worth their weight in gold.

14. The materials furnished by animals not only serve to heighten the "pomp, pride, and circumstance of glorious war," but, among rude nations, serve to supply some of the actual weapons for warfare. Among these are the teeth of the shark, the serrated projection of the saw-fish, the tail of the limulus or king-crab, and the poison of the rattlesnake.

Few who, at the ball or the concert, hear the violin "discoursing most excellent music," remember that it is necessary for the production of the sound, that hair from the tail of one animal should be brought into contact with the prepared intestine of another.

LESSON III.

COMMERCE, MANUFACTURES, AGRICULTURE, ETC.

1. It has been already stated that the quantity of tallow annually imported into Britain amounts to a million and a half hundredweights, or 75,000 tons; the number of hides and skins to about eleven millions; and the weight of horns of different kinds imported in a single year, into Liverpool alone, to thirteen hundred tons. It needs "no ghost to come from the grave to tell us," that such imports must employ a large number of vessels and of men, and that the various manufactures arising out of these materials, must furnish occupation to many thousand individuals. This is so obvious, that it need not be further urged; and to enlarge upon the subject, and pursue some of its ramifications, would demand a space greater than can be devoted to the present treatise.

2. But to assist the reader in tracing for himself the important influence, on human pursuits and happiness, which is thus exerted, a few figures connected with some

well-known departments, may advantageously be brought under his notice.

Let us take one of our most common fishes, the herring. The Board of Fisheries for Scotland informs us of the details connected with the boats, the nets, and the crews. A popular writer thus pleasantly introduces us to a locality, made animated and bustling for a time by this fishery, and glances at the sympathies and affections which are interwoven with its pursuit:—

"We lately visited a seaport town in the north-east of Scotland, during the herring season; and the scenes then witnessed naturally suggested the 'dry-as-dust' character of blue books, when compared with the living reality. The harbour was filled with a forest of boat-masts, moving fantastically with every swell of the water: towards sunset a thousand oars were dipped, and the boats swept out of the harbour and glided to the west end of the bay, then setting their bark-dyed sails, they stood out in hundreds for the open sea. As each skiff bounded over the ocean, 'wives,' 'mothers,' and 'daughters,' looked anxiously on; and the motley groups remained on cliff and beach till the receding canvas was lost in the distant horizon."

The following are some of the official statistics. The quantity of herrings caught and cured, in 1850, filled 687,401 barrels. In 1851, there were employed in fishing in Scotland and the Isle of Man, 10,480 boats, manned by 40,362 fishermen and boys, and the total number of persons employed on shore curing, amounted to 68,939. The total value of boats, nets, and lines, was estimated at 534,324*l*.

3. It is unnecessary to do more than refer to the pilchard fishery of Cornwall, the cod fishery of Newfoundland, the tunny fishery of the Mediterranean; the sturgeon fishery of the northern shores of the Caspian sea, especially of the rivers Wolga and Ural, and the manufacture of isinglass and caviare, the former from the air-bladder, the latter from the roe of the sturgeon.

The term "fishery" still continues to be applied to the annual capture of whales and seals. This is a custom, which, in the opinion of naturalists, were "more honoured in the breach than in the observance," for it serves to keep up the idea that these warm-blooded mammiferous animals, living in the sea, should, from that circumstance, be included among fishes. To form a just estimate of the importance of this "fishery," we must turn to America. It is stated by M'Culloch, that 700 American vessels, forming an aggregate of 193,798 tons, are so engaged, and that a very large proportion of this immense fleet is employed in the Pacific.

4. If we were to turn from the animal treasures yielded to the energy of man by the seas and rivers, and direct our consideration to the land, we should meet abundant examples of animals giving origin to trade and manufactures. From all the tribes of invertebrate animals, let us take but one species, the silkworm, and regard it as the motive power of vessels that convey the silk, and of machines by which it is manufactured. And like manner from all the vertebrate animals, let us select the domestic sheep, and note the influence it exercises on man. M'Culloch informs us that the imports of wool into Britain, in 1851, amounted to 41,810,137 lbs., that the value of the manufactured articles is estimated at twenty-six millions; and the number of persons employed in the different branches of the woollen manufacture 322,000.

If only these two animals were suddenly annihilated, or so changed that the caterpillar of the silkworm no longer spun a cocoon, and that the sheep were covered with hair like that of the horse, how vast would be the effect on man! How many millions of the human race might say with the afflicted Moor, "Othello's occupation's gone!"

5. Our attention has hitherto been directed principally to the uses to man of the bodies of animals, or portions of those bodies, or products derivable from them by human skill or labour. But this is not all. We must remember that in countries such as Great Britain and Ireland, the manure which the farm-yard supplies is a substance of so great value, that every endeavour is made by the skilful farmer to prevent any portion of it from being lost. The refuse of the glue manufactory,

and of similar works, is also valuable as manure; and fishes are occasionally taken in such quantities as to be used for the same purpose. Mr. Yarrell states, that "in the winter of 1829-30, sprats were particularly abundant: barge-loads, containing from one thousand to fifteen hundred bushels, bought at sixpence a bushel, were sent up the Medway as far as Maidstone to manure the hop grounds." We learn from the same author that farmers "distribute about forty bushels of sprats over an acre of land, and sometimes manure twenty acres, at the cost of twenty shillings an acre." The bones of the mammalia, when ground down, are sold as "bone manure," and are extensively in demand. The droppings of the sea-birds in remote localities are largely imported as guano, and give increased luxuriance to our crops. Nor are the vertebrate animals the only class from which fertilising products are supplied. The humble molluscs, that have elaborated carbonate of lime to form their shells, have left deposits of great value to the agriculturist. The coral-building polypes have likewise contributed with other labourers to the same end. The vast deposits of chalk, which furnish lime to the farmer and the builder, are legacies which have descended to us from marine creatures that have passed away. The utility of such animals to man is therefore felt for ages after their own existence has terminated.

We turn now to consider the uses of the living animals to man, in reference both to his labours and to his amusements. And first in importance must be placed agriculture.

6. Agriculture.—The ox, the horse, and the ass are so associated, in the minds of all who are likely to read these pages, with the labours of the husbandman, that the slightest reference to them is sufficient. In the sacred volume they are frequently mentioned; and the humane spirit of the Mosaic dispensation is evinced in many of its ordinances regarding them. "Thou shalt not muzzle the ox when he treadeth out the corn" —"Thou shalt not plow with an ox and an ass together"—are familiar examples, and worthy of being ever held in remembrance. The spirit of the injunc-

tion does not pass away with changes of habits and customs.

> "Joyous, the impatient husbandman perceives
> Relenting Nature, and his lusty steers
> Drives from their stalls, to where the well-us'd plough
> Lies in the furrow, loosen'd from the frost."

But without reference to field labour, we not unfrequently find that animals by their ordinary habits, and in the discharge of their ordinary functions, become the unconscious instruments of good. The unseen labours of the earth-worm, in perforating, and thus opening the soil, is a home example of this well-known fact; and if we direct our attention to the Spice Islands, "whose breath is balm," we discover that birds are there the most effective agents in the diffusion of seeds. Elsewhere it is no less certain, that insects are the means of carrying the fertilising pollen to plants, which would otherwise remain barren.

There are some animals which under certain circumstances become injurious to the farmer, by their numbers and destructive powers. But this is on rare occasions, and in general they may be regarded as friends rather than foes. But, waiving, for the present any discussion on this point, there can be no difference of opinion respecting the services of those animals that prey upon such assailants, and reduce their numbers. Thus, the owl mousing over a field; a rook pulling up the grass to destroy the cut-worm at its root; the woodpecker extracting the timber larvæ from the trunk of the tree; and the pretty little "lady-birds" (*Coccinellæ*) feeding on the aphides or plant-lice—do not come before the farmer in "a questionable shape;" he may hail them as friends.

7. If we regard animals, not merely as to what we term agricultural pursuits, but as the companions and helpers of man in other ways, and especially in other countries, the list would become of great length, and an enumeration of the various services thus rendered would "stretch out to the crack o' doom." The elephant and the camel, the llama and the reindeer, naturally suggest themselves as examples. The horse of the Bedouin Arab is not

merely a servant, he is a companion and friend, treated with kindness from birth, and made the playmate of the Arab children.

To mention the dog as the companion of man, is to tempt us into the region of poetry and romance; to give us visions of the faithful servitor of Ulysses, of Gelert, the "gallant hound" of Llewellyn; and of Roswal, the noble stag-hound in Sir Walter Scott's tale of "The Talisman," seizing the traitor marquis by the throat, and pulling him from his saddle to the earth. Even if we limit ourselves to sober facts and well-ascertained realities, it is difficult to keep within bounds, when every country where the dog is known offers testimony of his usefulness. If in imagination we climb the Alps, we meet the sagacious dogs of the monastery of St. Bernard; if we take up some account of the Arctic voyages, we find the Esquimaux dog is presented as "the patient and enduring friend, the bold, active, and experienced hunter, the laborious beast of burden, the indispensable assistant of his master under all circumstances and in every emergency." I must, therefore, leave each reader to pursue the subject for himself.

8. The natural powers of other races of animals, improved and cultivated by man, have often afforded him worthy service. Thus, the rapidity of the carrier pigeon was made available when the wonders of the electric telegraph were yet unknown. Even a knowledge of the habits of animals yields occasionally valuable results, from the indications they afford. The increasing number of sea-birds prognosticates to the mariner that he is approaching land. The flight of birds in the desert points out the direction of the long-desired pools. On one occasion, Gordon Cumming, that most fearless of hunters, was in great distress for want of water, when he perceived a "sassayby," a species of antelope, that drinks every day. "Fresh vigour, with the hope, returned, and he pressed forward." The remainder of the narrative is given in his own words: "Before I reached the old grey tree, I observed a small flight of manaqua partridges, flying across my

path, in a westerly direction. It was impossible to tell, until I should see a second flock of these, flying at a different angle, whether the first flock had come from, or were going to, water. For this I accordingly watched; nor watched long in vain. A considerable distance ahead of me I detected a second flight of these birds, likewise flying westerly; and it was evident, from their inclination, that they held for the same point as the first had done. Shortly afterwards, the first flight returned, flying high above our heads, uttering their soft, melodious cry of 'pretty dear! pretty dear!' I then rode in the direction from which the birds had come." It is almost unnecessary to add, that his search was now crowned with success. To the indications afforded to his observant eye, by the antelope and the birds, he was, under Providence, indebted for an escape from the agonies of thirst—perhaps for the preservation of his life.

9. SPORTING.—

"The pleasantest angling is to see the fish
Cut with her golden oars the silver stream,
And greedily devour the treacherous bait."

"When in a wood of Crete they bay'd the bear
With hounds of Sparta; never did I hear
Such gallant chiding."

Man makes use of animals, not only for his wants and for his luxuries, but also for his "sports." The beast, the bird, and the fish thus minister to his amusement. So widely prevalent is this propensity, and so independent of the varying fashions or customs of men at different periods, that our great poet, with his deep insight into human nature, has on many occasions made reference to field sports, in the spirit that only a sportsman could evince. The fondness, or more properly the passion, for fishing, for shooting, or for hunting, causes privations to be endured and dangers encountered, which, under other circumstances, would most sedulously be avoided. That animals "furnish forth" those "sports" is a great acknowledged fact. To write upon the subject is not my intention. I have in me nothing of the spirit which prompted Duke Alexander of Gordon to exclaim, when he had killed the famous old stag with seventeen tine, "Now, I can die happy." On the contrary, it occasionally happens, when reading some feat of sporting, skill, or daring, that instead of admiration of the man, my feeling is that of sympathy for his victim.

Besides being himself the destroyer, man has, for his own amusement, made animals combat with other animals, and ocasionally with man. The "sports" of the Roman amphitheatre furnish the best-known example of this in former times; the Spanish bull-fight in our own:—

> "Foil'd, bleeding, breathless, furious to the last,
> Full in the centre stands the bull at bay,
> 'Mid wounds, and clinging darts, and lances brast,
> And foes disabled in the brutal fray:
> And now the matadores around him play,
> Shake the red cloak, and poise the ready brand:
> Once more through all he bursts his thundering way—
> Vain rage! the mantle quits the conynge hand,
> Wraps his fierce eye—'tis past—he sinks upon the sand!"

In our own islands bull-baiting and bear-baiting are now illegal; and other "pastimes," once considered manly, are likewise regarded as the relics of a barbarous age. May the time speedily come when they will be utterly abolished, not merely by the terrors of the law, and the expression of public feeling, but by the growth of a kindlier and more humane spirit towards the brute creation!

10. SANITARY.—If we but think of the impurities with which both land and water are daily laden, and the vast amount of animals of various kinds that die every day, it is obvious that unless there existed a sanitary police, more vigilant and more universal in its operations than any of human enrolment, the air would become tainted, and the ocean itself impure. Such a police is found among animals themselves, and it bespeaks the consummate wisdom by which all the vast framework of animated existence is carried on, that the operations are incessant, and for the most part unseen.

> "Wheresoever the carcase is, there will the eagles be gathered together."

Minute particles of animal matter diffused through seas and rivers, instead of undergoing the process of chemical decomposition, are laid hold of by animalcules, whose existence is made known to us only by the microscope. Others, not so minute, in conjunction with polypes, crustacea, and mollusca, are at work in freeing the water from animal impurities. Animals, some of them of larger size, jelly-fishes, star-fishes, sea-urchins, crabs and mollusks, attack dead or decaying bodies. Fishes of different species are efficient labourers in the same field. If the body be of large size, and rises to the surface, aquatic birds, of several kinds, hasten to partake of the spoil. Under the joint efforts of so many labourers, aided by chemical agencies which are ever at work, the largest animal body, even that of the whale, rapidly disappears, and its component parts, instead of generating disease and death, have gone to the support of life and animated existence, in a vast variety of forms.

11. The arrangements regarding the sanitary police for the land are not less efficient than those for the sea. In some countries numbers of rapacious birds are on the watch to attack the body of any large animal, almost as soon as it has fallen. Gordon Cumming, after describing his encounter with a lioness, and the death of the animal, says: "Before we had proceeded a hundred yards from the carcase, upwards of sixty vultures, whom the lioness had often fed, were feasting on her remains." Beasts as well as birds are ready for such banquets, and gorge themselves to repletion. Insects of different classes take an efficient part in the work. After the muscular fibre has been removed from the carcase by beasts and birds, the skeleton is cleaned of every particle of flesh by those pigmy assailants. In countries where the larger animals which prey on carrion are not found, insects are the primary agents for its removal. Some pierce the skin; others deposit their eggs in the flesh; while wasps, ants, and beetles of several species, promptly give their assistance.

12. To trace out more in detail the part borne by these different agents, in the removal of dead and putrifying carcases, would more properly belong to a treatise on the *habits* of animals than to one on their *uses* to man.

Enough has been said to show, that to animals we are indebted for much of that purity which the earth presents, and that freedom from noxious effluvia which the atmosphere retains. Millions of animals die annually in the sea, or are poured into it, with other impurities, from mighty rivers; yet the ocean is as untainted now as at its birth, unaffected alike by age and by corruption.

> "Such as Creation's dawn beheld, thou rollest now!"

13. I have endeavoured in the preceding pages to point out some of the advantages which man derives from the inferior animals. They not only augment, in many ways, his physical comfort, but may, in a certain sense, be said to be important means of human civilization and advancement. To the eye of the artist, the flight of the sea-birds about the headlands, whereon they build, is not more pleasing than their cries commingled with the sound of the waves upon the beach. The one is in keeping with the other. Not only do birds and beasts give animation to the scene, but they impart to it characteristic features, which nothing else would supply. The camel is associated in our minds with the glare of eastern skies and of sandy deserts; the reindeer with wide-spread snowy wastes; the chamois with Alpine solitudes; the lowing herd with grassy pastures and quiet homesteads. In like manner, we associate the condor with the scenery of the Andes; the birds of paradise with the islands and legends of another hemisphere; the domestic fowl with the thriving farm-yard; the bittern with the marsh, and with all that is waste and desolate. What would be the effect on the senses of man, if all those varied living objects, on which his eye rests, were converted into stone? if those sounds, that fill the air with the evidence of animate existence, were stilled for ever? Who, if deprived of it for a time, would hesitate to term the "carol of a bird" precisely what the "Prisoner of Chillon" has done—

> "The sweetest sound ear ever heard?"

But these sights and sounds fulfil a higher purpose than merely affording gratification to the eye or the ear. They speak of a providential care that never slumbers;

that guards the young, feeds the mature, and in the most wondrous and diversified ways provides for the continuance of the species. Those students of nature whose knowledge has had the widest range should, from that very circumstance, be the most willing in another department to "become as little children." They are prepared to receive the great and consolatory truth, conveyed in the simple words:—

"Are not two sparrows sold for a farthing? and one of them shall not fall on the ground without your Father.

"Fear ye not, therefore, ye are of more value than many sparrows."

ROBERT PATTERSON.

Political and Domestic Economy.

BY R. H. WALSH.

LESSON I.

FRUGALITY AND PRUDENCE.

"And when he had spent all there arose a mighty famine in that land; and he began to be in want."

1. INSTEAD of wishing, like those who are called Communists, to deprive the wealthy of what they possess and divide it among others less affluent—or seeking, like Socialists, to make Government the head of each working establishment, with powers to arrange how much shall be paid to the labourers and employers respectively, the mode of conducting the business, and the distribution and destination of such property as belonged to any one who dies, (if indeed under a system of this nature private property could be said to exist)—it is far better to consider how each may earn money for himself, without taking away from others, or interfering in any manner whatsoever with what they are entitled to.

2. And to one who has not seriously reflected on this subject, it will be astonishing to see all he can do for himself if he only set about it in earnest, instead of wasting his time and energies in abusing the rich and coveting their possessions, or seeking to control them.

He will find it can readily be explained with what facility he can improve his condition by using the opportunities within his reach; and if not satisfied by the reasons offered, he may be convinced by innumerable examples of persons who have succeeded in life with no greater advantages than he had. Most commonly, indeed, without looking beyond the circle of his own immediate acquaintances and neighbours, he may discover many who have got on well and made themselves comfortable without any better opportunities than he had at starting, merely because they turned those that presented themselves to good account. And he may also learn that had he acted like them, not only would his material comforts have been increased, but, moreover, he would be in a position far more favourable to the advancement and preservation of moral worth.

3. The habits, inclinations, and desires of individuals presenting considerable variety, the means by which they hope to satisfy themselves differ in a corresponding degree. Some hope to attain a position of wealth and eminence so high as to raise them far above the rest of their class, and place them among the great ones of the earth; while the aim of others is less ambitious, they only wishing to secure themselves a comfortable position without advancing in any remarkable degree beyond those in their own walk of life who are pretty well circumstanced. As for the more aspiring, it is not here intended to treat of them at any length. Those who become very rich or very great are necessarily few in number, and aided usually by extraordinary advantages of some kind or other; which shows that it can benefit the public generally but little to consider the means whereby a success can be attained which is beyond the reach of most. Besides, even when it is attained, its effects in promoting the true welfare of its possessors are extremely doubtful, the greatest success often disappointing expectations, and being purchased at the expense of such excessive toil of mind and body,—nay, sometimes at the sacrifice of the best principles of our nature—so that the struggle to attain it may not only produce misery or even vice while it lasts,

but also lead to nothing in the end but vexation and remorse.

4. The more moderate and less painfully exciting exertions which suffice to secure a competence, and so render the condition of its owner easy, without elevating him greatly above his original sphere of life, are a useful, salutary, and even agreeable exercise, and their result affords no disappointment because it had been foreseen and understood from the beginning. A person may form a very exaggerated notion of a state of life of which he has had no experience because removed far above him, and feel proportionably disappointed when after making every sacrifice to reach it, he finds the reality far different from what he anticipated. It is otherwise when all that is desired is to be comfortably settled in our own rank of life; as then nothing is sought but the means of avoiding inconveniences and privations occasionally experienced, and securing permanently those comforts which had previously been enjoyed at times only. This end may be acquired without the aid of personal qualities of rare and superior description, or other extraordinary advantages, and solely by the exercise of that *frugality* and *prudence* which it is in the power of every one to make use of.

5. From the humblest class of workmen to the highest, including professional men, all must exercise the qualities of prudence and frugality in order to succeed; but the mode in which they are called upon to practise them presents an important difference. By a bountiful provision of Providence the humbler classes, who, from imperfect education, are less able to subject themselves to restraints, are not obliged to exercise them to the same extent as their superiors; if they attend to the proper management of their earnings they are pretty sure to get on well. The educated classes must not only take similar precautions, but, besides, they will not be in a position to make anything on which to practise them, unless by a previous long and sometimes painful exercise of toil and forethought they have fitted themselves to pursue the vocation they have adopted. Any one in good health can fit himself after a short

while to perform the ruder operations of agricultural or manufacturing industry. No mental exertions need be undergone, nor is there the trouble of acquiring that nice manual skill and address which the higher departments of labour demand. Further, the learner is not obliged to work long without remuneration, as after applying himself to the occupation for a brief period he can perform it well enough to make it worth while for others to pay him for his labour; so he does not want the aid of prudence to induce him to undergo the trouble of preparing for an employment that will yield him no return until a distant day. He has little more to do than exercise the powers which nature has given him, and receive forthwith remuneration for his conduct. When work of the kind he performs is going, it can usually be had by all of his class; and any one who makes a prudent use of what he naturally receives in prosperous times, need never experience want.

6. By not indulging in superfluous expenditure for the course of a few years, so much may be laid by in a bank as will support the labourer when the times are hard, work not to be had, and provisions dear; or enable him to emigrate to the colonies, where the reward of labour is high, the abundance of land renders the necessaries of life remarkably cheap, and the scarcity of workmen compared with the demand for them leads employers to offer high wages to such as they can obtain. The English labourer, whose earnings when at work are usually considerable, can easily secure himself against adversity in this manner; but, it is to be regretted, this is not done as often as it might. Some years ago there were very many engaged making railways, and when some of these were subsequently discontinued, the navvies in great numbers were reduced to destitution, though previously they had been earning on an average more than 40*l.* a-year each. Unhappily, the beer-shops and ale-houses had received much of their earnings, the savings'-banks very little.

7. In Ireland wages are lower than in the rest of the United Kingdom, yet even there the labourer might do

much for himself out of his scanty pittance. How few of them spend less than sixpence a-week, or 1*l.* 6*s.* a-year, on tobacco, the most that can be said in defence of which is that it is not *always* injurious to the health, the active habits of some enabling them to endure stimulants which to persons more sedentary would be absolutely destructive! The consumption of spirits absorbs a much larger portion of the earnings of those who indulge in it; and between both many a workman in the course of a few years spends from 20*l.* to 50*l.*, besides being prevented from earning what he would otherwise have gained but for the idleness, sickness, and various misfortunes so often produced by dissipation. So true it is that the heaviest taxes are those which a man imposes on himself by his own misconduct, and the very best assistance which can be afforded is to lay before him their amount and teach him how to remove them.

8. Those who recommend prudence and frugality to the humbler classes must carefully bear in mind that these qualities are required even in a higher degree amongst those of more elevated rank, although, indeed, the effects of neglecting them do not so often lead to actual destitution. Success in the learned professions and higher branches of industry cannot be purchased without patient toil and intense study to fit one to exercise an employment of such a nature. During much of the time so engaged, the learner receives little or no payment for his trouble: and unless be has sufficient forethought and prudence to endure these probationary labours, he will never make much in his business. And when he has mastered the difficulties in his way, he must, like the poorer individual, regulate with frugality the expenditure of his gains; for should he not do so, though it is unlikely he will sink into actual destitution, yet he will suffer consequences to him just as bitter, and feel as much sorrow and anguish in falling with his family into reduced circumstances, as the man in an humbler rank of life experiences when exposed to actual privation, or else driven to avoid it by seeking shelter in the poorhouse.

9. **Moral Effects of Frugality and Prudence.**—Not only will those who cultivate these qualities secure themselves against want and destitution, and preserve themselves from falling into reduced circumstances, but, besides, the course of conduct they adopt must render them better men, and give them reason to enjoy greater mental tranquillity. For example, take the case of a labourer, who, instead of running through his wages as fast as he gets them, deposits in a neighbouring savings'-bank whatever is not wanted for immediate consumption, and then let us trace the natural effects of his conduct. He no longer frequents public-houses, and other objectionable places, but becomes sober and well-conducted. When any sudden calamity comes on, such as a failure of food crops, or a state of temporary depression in the business he follows, he can make use of what he accumulated in prosperous times, and subsist on it until prospects brighten, or employ it to remove him to some other locality, instead of being driven by want to theft, or robbery, or brought to the poorhouse. When sickness or old age comes on, instead of languishing in misery, or else becoming a burthen to others who might be badly able or else unwilling to bear it, he is in a position to support himself from his own resources. And at the hour of death, his last moments are not disturbed or tormented by the thoughts of leaving a helpless family exposed to misery; but he is cheered by reflecting he has done his duty, and by his industry and frugality placed them in a way of being maintained until they become capable of earning a livelihood by their own exertions.

AGAINST A RICH MAN DESPISING POVERTY.

If well thou view'st us with no squinted eye,
No partial judgment, thou wilt quickly rate
Thy wealth no richer than my poverty,
My want no poorer than thy rich estate:
Our ends and births alike; in this, as I,
Poor thou wert born, and poor again shalt die.

My little fills my little-wishing mind,
  Thou having more than much yet seekest more:
Who seeks, still wishes what he seeks to find;
  Who wishes, wants: and whoso wants is poor;
    Then this must follow of necessity—
    Poor are thy riches, rich my poverty.

Whatever man possesses, God has lent;
  And to his audit liable is ever
To reckon how, and where, and when he spent;
  Then thus thou bragg'st thou art a great receiver.
    Little my debt, when little is my store,
    The more thou hast, thy debt still grows the more.

But, seeing God himself descended down
  To enrich the poor by His rich poverty;
His meat, his house, his grave, were not his own;
  Yet all is his from all eternity:
    Let me be like my head whom I adore!
    Be thou great, wealthy—I still base and poor.

FLETCHER.

LESSON II.

LABOURERS AND EMPLOYERS.

"Servants be obedient to them that are your masters, with good will doing service, as to the Lord, and not to men.

"And ye masters do the same thing unto them, forbearing threatening; knowing that your master also is in heaven; neither is there respect of persons with him."

1. THE worth of labour, like that of everything else which is bought and sold, changes considerably from time to time; and during the transition disputes not unfrequently arise: the workmen, when their labour becomes less profitable than usual to the employers, being unwilling, nevertheless, to submit to a reduction of wages, and when it becomes more so, attempting to secure a more rapid and greater advantage than that conceded. It is only fair and reasonable that wages should be adjusted to the worth of what they are given for; and to this level *in the end*, as shall presently be shown, they must inevitably rise or fall. But it is deeply to be regretted the good sense of masters and men does not lead them to settle

their terms with one another *promptly and amicably*, instead of subjecting themselves to heavy pecuniary loss by their unhappy contests, and inflicting on the community at large the far more serious evils which result from the angry spirit and bitter feelings thus engendered between the wealthier and poorer classes.

2. At Preston lately, where 18,000 persons remained idle for thirty-seven weeks, because the employers refused to raise their wages two shillings in the pound, the men, besides spending any little savings they might have laid by as a provision for old age or infirmity, lost in addition about £250,000, such being the amount of what they would have earned had they kept to their work. Even had they been successful in their attempt to force the masters to yield to their demands—which they were not—it would have taken many years before the advance in wages they wanted would have sufficed to repay them what was lost in the thirty-seven weeks during which they received nothing whatsoever. And as they failed, not only was their pecuniary loss rendered irremediable, but they suffered likewise the far greater penalties entailed on them by habits of idleness and lapses into vice, occasioned by their long cessation from labour, and which, after its resumption, remained as a scourge to punish the follies of those who had been led astray, and the guilt of the leaders who had deceived them.

3. Sometimes, perhaps, employers are not wise or just enough to raise wages when they ought, without waiting for some open manifestation of discontent; and so far they are answerable for the contests which follow. But most of the blame in such cases must be attributed, we fear, to the workpeople and their advisers. The men of Preston might easily have assured themselves that the masters, who were perfectly aware, both from their accounts and their knowledge of prices and business generally, what wages they could afford to give, and yet leave themselves a reasonable profit, would not have remained for any considerable length of time without labourers unless the advance demanded were so high that it could not possibly be conceded. There are some,

indeed, who think that manufacturers and other employers lose little or nothing while their men won't work; and that, accordingly, no matter how fair the demands of the latter, they are in a position to slight them with impunity, and must, finally, have everything their own way. But this is quite a mistake.

4. If a manufacturer be long without workmen, he cannot supply his customers, and then they go elsewhere, never, perhaps, to return to him. And he may have formed engagements to furnish certain goods by a given day, or he may have depended on selling before some particular time in order to meet debts then to fall due; and if he fail to fulfil his bargain, he may be exposed to a penalty in consequence; or if he be unable to satisfy his creditors when agreed upon, they perhaps will refuse to wait any longer. In either case he is at loss and inconvenience, and sometimes he is utterly ruined. And even though he be not placed in such embarrassing circumstances, he must, at all events, be at the cost of keeping his works and machinery in order, and paying rent and taxes for his establishment, though nothing whatsoever is produced for him while labour remains at a stand-still. In fact, it is evident on reflection neither party can fix the rate of wages at their pleasure, and it must in the end settle down at what labour is worth. The men cannot go on without working as long as they please, and must therefore eventually agree to take what the masters offer. And the masters, on their side, rather than remain without men, will offer as much as they can afford in order to get them back again, or others in their place.

5. But, it will be asked, how is it to be decided what is the fair rate of wages? Why does it differ from trade to trade and from time to time at the same place? Why is it so dissimilar in different countries? Or, to select particular instances, why does the Englishman earn as many shillings as the Hindoo does pence; or why is the Australian colonist better paid for his labour than the inhabitant of the United Kingdom? These are important questions, not altogether free from difficulty,

but they admit of satisfactory answers, and it is to be hoped that what follows will be found to throw light on the subject.

6. WHAT SETTLES THE GENERAL RATE OF EARNINGS IN EACH COUNTRY.—If each person worked by himself, without any assistance from others, it would be easy to perceive what determined the amount of his earnings. They would consist of whatever he produced by his skill and industry, and thus depend on what may be called the productiveness of his labour. And if a number of persons work together, some doing one part of the operation, others another, and a third party furnishing implements and materials, it is equally plain that the amount earned by all will depend on the productiveness of labour, though there may be difficulty in ascertaining how much has been produced by each one in particular, and how much, therefore, should go to his share. But before entering on this latter question, which if answered would only show in what proportion what is produced by all is distributed among them, we can see without proceeding further that the reason why the earnings of the people in any one country are higher than elsewhere, is simply because their labour is more productive. The more of an article a set of men can make or prepare, the more of it is at their disposal should they wish to use it. And according as such produce can be sold for more or less, and according to the prices of other articles, so will be the quantity either of money or of goods in general, which they can obtain in return for their industry, and so produce for themselves, as it were, indirectly.

7. Earnings are very high in places like most of our colonies, the inhabitants of which are supplied in unlimited abundance with land and other natural agents on which to exercise the extremely efficient skill and industry acquired in old and densely-peopled countries. In the new world a few men can raise far more agricultural produce than could a much greater number here, since owing to the abundance of land they may not only choose the best in reach, and afford to pass by what is inferior; but, besides, instead

of being obliged to cultivate and enrich the soil in that laborious and expensive manner which is necessary in order to derive a large amount of produce from a small extent of surface, they may take a crop or so from the land at very little cost and trouble, and then leave it to recover itself and resume its natural fertility while they work elsewhere. In pastoral pursuits they have manifestly far greater advantages; and with respect to the products of the forest even yet more, nothing being required to provide a supply but to fell and remove what they want, while at home the expense must be incurred of planting the trees in the first instance, and then protecting them from injury for many years to come. Labour, accordingly, commands a great return in the shape of agricultural produce and raw materials generally; and articles of this description being exported and exchanged for foreign goods or money, a large amouut of either can thus be gained in the general market of the world by the labour of the colonists. As for articles of domestic produce other than raw materials, they have not the same advantages in procuring them. In some cases, indeed, when little labour is requisite for converting them from a rude to a finished state, the facility for obtaining them in the former condition insures an almost equal advantage in the latter. Thus they have cheap bread notwithstanding the high earnings of bakers; the cheapness of corn counterbalancing the dearness of labour

8. But when much labour must be expended, the high rate of wages which must be paid to the workmen renders the articles dear in proportion, and prevents people from having any greater command over them, despite the large amount of their earnings, than the inhabitants of other places, where wages are lower. Thus furniture and dress, unless when imported, and the services of others, which even those in a humble walk of life occasionally purchase, are so very dear in the new world that they cannot be had as easily as in most parts of Europe even by persons whose earnings are not nearly so great. On the whole, we may see, the condition of labourers in places like the colonies

and the United States, is superior to that of those in the old world; but the few drawbacks, just noticed, indicate at the same time that it is not so very far preferable as might appear at first sight from the large amount of money to be earned and the moderate prices of most articles of prime necessity.

9. It happens often, that despite the advantages of abundance and fertility of soil, the more barren and thickly-peopled country is the richer of the two in proportion to the number of its inhabitants, their superior energy and skill making up for the want of equal natural facilities for production. It would require many times the number of Mexicans to extract as much wealth from their miraculously fertile dominions as the thrifty Dutch acquire amidst the swamps of Holland. And, indeed, there can be no stronger instance of how much more the qualities of man are the cause of wealth than the nature of the soil than is furnished by California. Within the last few years, it has passed from the idle Mexicans to the active citizens of the United States; and from an uncultivated waste, it has been quickly transformed into one of the richest regions of the American continent. An intermediate state of things appears from a comparison of England and East India. The Hindoo is not without skill and industry; the country he inhabits is generally remarkably fertile, and the climate in many parts so favourable, that the harvest comes in twice a-year. Yet, despite all that, the greater energy and industry of the English, and the superiority of the machinery and implements with which their labour is aided, are so powerful in their effects, that if we compare the population and production of England and Wales, with that of the most prosperous part of East India—the portion composing the British dominions—it will be found that eighteen million people, inhabiting the sixty thousand square miles which form the surface of England and Wales, succeed in producing a greater amount of wealth—in earning more for themselves collectively and not individually merely—than a population of Hindoos nearly six times as numerous and

possessed of a territory about eleven times as extensive, besides being in many places blessed with a better climate and richer soil.

TOIL AND BE GLAD.

Toil, and be glad! let industry inspire
Into your quicken'd limbs her buoyant breath!
Who does not act is dead, absorpt entire
In miry sloth, no pride, no joy he hath:
O leaden-hearted men, to be in love with death!

Ah! what avail the largest gifts of heaven,
When drooping health and spirits go amiss?
How tasteless then whatever can be given!
Health is the vital principle of bliss.
And exercise of health. In proof of this,
Behold the wretch, who slugs his life away,
Soon swallow'd in disease's sad abyss;
While he whom toil has brac'd, or manly play,
Has light as air each limb, each thought as clear as day.

O, who can speak the vigorous joys of health?
Unclogg'd the body, unobscur'd the mind:
The morning rises gay, with pleasing stealth,
The temperate evening falls serene and kind!
In health the wiser brutes true gladness find:
See! how the younglings frisk along the meads,
As May comes on, and wakes the balmy wind;
Rampant with life, their joy all joy exceeds:
Yet what but high-strung health this dancing pleasaunce breed?

Thomson.

LESSON III.

DIVISION OF EARNINGS.

"The drunkard and the glutton shall come to poverty: and drowsiness shall clothe a man with rags."

1. Having explained why the people of some countries earn more for themselves collectively than their neighbours, we have now to consider how wealth when produced is divided among the classes to whose joint exertions it is due. How often do we hear complaints that the many are little benefited by the riches they are instrumental in creating by their toil, because a few contrive to monopolize so large a share in return for the capital they employ, and the services

they render, that but a small portion remains to remunerate the rest for their labour. If this were true, it would be very deplorable; but we trust on examination it will prove to be erroneous, and that it may easily be shown how trifling are the profits afforded to employers by capital, compared with its effects in augmenting wages; and that the ordinary reason why some labourers are paid so much higher than others, is simply because the services they perform are more difficult or disagreeable, or require qualities and capacities not often to be met with.

2. One of the most profitable branches of industry is the cotton trade, and if it appear that even there the profits of capital are small compared with the wages of labour, it may safely be concluded they are so everywhere. Now, from calculations made by persons highly competent to perform such a task with accuracy, we learn that for every pound paid in wages to the operatives, only from two to three shillings go as profits to the manufacturers. This teaches a useful lesson, as workmen are prone to imagine they would possess princely fortunes were they possessed of their masters' profits. In reality we see that if the men owned the capital and managed it as well as the employers, they would raise their wages only two or three shillings in the pound. How much more they could do for themselves by acquiring additional skill and industry is shown in the calculations already referred to, where we find that wages in the cotton trade vary from about thirteen shillings a-week to nearly three times that sum; the better-class workmen being paid at the rate of from thirty shillings a-week upwards. This places under the eye, as it were, in a striking point of view, that while by appropriating their employers' income the labourers would be only two or three shillings in the pound richer than at present, it is in the power of each one, by acquiring additional skill, and becoming more industrious, to earn two or three pounds where now he makes but one; that, in fact, while by confiscating what belongs to others, he could gain but two or three shillings, he might in the same time, by improving

himself instead, increase his earnings by one or two pounds.

3. The mistake a workman is most apt to fall into, is that of contrasting his wages alone with his employer's revenue, and thence concluding that a trifling deduction from the latter, which might be allowed if the master chose, without his suffering any very great inconvenience, would be sufficient to raise wages enormously. Were the master, he might think, with 5,000*l.* a-year to pay him, say, 100*l.* annually instead of 50*l.*, he would be twice as rich as before, and the master very little poorer. This is true, and might answer very well, if there were but a single workman in the case. But there is no reason why so much should be done for one in particular; and if it were attempted to serve every one in the same manner—if the rich were to set about doubling the wages of all they employed—so far from their income sufficing to confer benefits so widely among the working-classes, the entire amount when so distributed would come to an end long before the process of doubling had been completed. For the utmost that could be done in that way, as has previously been shown, would be to increase wages a few shillings in the pound.

4. Effect of Capital in Raising Wages.—Far the greater part of the revenue arising from the employment of capital goes as wages to workmen, and not as profits to the masters. This may be established by comparing the earnings of people among whom capital is abundant, such, for example, as those engaged in the English cotton manufacture, with those of tribes who have little or none. Perhaps, indeed, there is no place where there is absolutely nothing that can be called capital, but there are some where there is scarcely any—as, for example, a few parts of Africa, and various islands in the Pacific inhabited by savages. And we find the people so circumstanced are wretchedly poor, their labour producing little for want of capital, that is, for want of implements and machinery to make it effective, of food and other articles to support the labourer while he devotes himself to steady industry, and of materials and seeds to work up or commit to the soil.

5. A labourer in this country often thinks himself poorer than he ought to be, and is inclined to attribute it to the riches of his wealthier neighbours; or, at all events, he thinks they are not of the least benefit to him. Yet if his condition be contrasted with that even of princes among savages, it will be found he enjoys luxuries utterly beyond their reach. And if it is so when compared with princes, what must it not be as regards the mass of the people they rule? This question may be difficult to answer exactly; but probably we shall be within the mark if we state that twenty savages produce but as much as one English labourer earns for himself, independently of his master's profit; and all this because the one is assisted by capital, and the others are not. In figures this will appear clearer, and may be put as follows:—When labour unassisted by capital would produce what would be worth 1*s*., labour assisted by capital would produce 22*s*. or 23*s*. And of this extra produce about 19*s*. goes to the labourer, and the remainder only to the party who supplies the capital.

6. Why some are paid much more for their Labour than others.—A carpenter, without working any harder than a common field-labourer, earns about twice as much; and a cabinet-maker, in like manner, is far better paid than a carpenter. And if we proceed to examine the scale of remuneration throughout the different trades and professions, we shall find an almost endless variety in the amount of earnings in each. But there is nothing unfair in this, as the reason why one kind of labour is higher paid than another is because it is more difficult to find persons properly qualified to perform it. This it is which renders it scarce in proportion to the demand, and so increases the value. Sometimes the scarcity of labour results from there being few persons *able* to perform it efficiently, and sometimes from there being few who are *willing* to do so; or it may happen that both circumstances combine, which renders the labour in question more valuable than might be expected, were one of them alone taken into account. A few examples will make this clear:—

7. According as the preparation is more expensive, the fewer will be able to adopt the occupation. Some may be prevented from want of means, and others, though rich enough, may fear to incur the expense of preparation, lest if the business were not properly learned, all the outlay would be thrown away. For it is scarcely necessary to mention that it is not because the training and education of one person is unusually expensive that his earnings are higher than average; but it is because the preliminary expense prevents many from entering the business. It is not uncommon for a father after bearing the cost of preparing his son for the bar, or the medical profession, to find it all thrown away, the son being unable to make anything by the business, from not having learned it sufficiently well. But when any trade or profession has been mastered, the expense of preparation produces its effect by lessening the number of competitors. It requires more time and money to become a carpenter than a field-labourer, and more to become a cabinet-maker than a carpenter; and therefore the cabinet-maker is better paid than the carpenter, and the carpenter than the field-labourer. And so on if we trace the effects of this cause throughout the different kinds of occupations, its influence will be found to be universal.

8. Again it happens occasionally that few are born with the talents necessary to attain a high degree of excellence in certain callings, and this by limiting the supply of qualified persons raises the remuneration of those who are so. One has a great genius for painting, another for acting or singing, a third for argument and oratory; and if these cultivate their talents properly, they will be enabled to earn immeasurably more, as painters, actors, singers, or advocates, than others who work just as hard and have spent quite as much in preparation, but are not blessed with equal abilities.

9. In the cases already noticed, labour is highly paid because few are able to perform it. But if an employment be unhealthy, dangerous, or otherwise disagreeable, none will be willing to undertake it unless they can get more than in those lines of business not equally exposed

to such disadvantages. The trade of a house-painter is unwholesome, that of a mason or slater dangerous, and that of a butcher disgusting; and accordingly painters, masons, slaters, and butchers are better paid for their labours than many tradesmen, such as carpenters and others, who work as hard, and spend as much in setting themselves up, but pursue occupations of a more agreeable nature.

10. The apparently extravagant remuneration of a successful opera-singer affords a striking instance of the effect in raising wages of both classes of causes when combined. Few are gifted with the vocal powers essential to excellence as a singer, and of those who are so, none can attain success without devoting much time and expense to the cultivation of their talents. Accordingly few are *able* .to be successful singers; but of those who might be so if they chose, many are *unwilling* to come forward, owing to the prejudices prevailing against those who appear on the stage. This explains the high remuneration of such as succeed, the number of those who might be able to compete with them being very limited, and that of those who are willing as well as able yet more so.

11. It is worth noticing that wages in general are more nearly equal throughout different occupations in some countries than others. For instance when education is general, clerks, accountants, and the like, will not earn a great deal more than mere manual labourers, as it is in the power of most to bring up their children to the more intellectual calling should they have any particular inducement to do so. When education, on the contrary, is not diffused, few have any choice in the matter; and although the accountant may earn more in proportion to the difficulty of his business and the expense of learning it than the common day-labourer, persons of the latter class will not be able to compete with him. Again, if the people are for the most part poor, they will not have the same objection to undertaking occupations of a disagreeable nature as if they were in a more comfortable position. Dirt will have little novelty for them, and cause scarcely any additional repugnance to adopting a calling with no other objec-

tionable characteristic. Neither will unhealthiness have much effect in raising wages under such circumstances, for few occupations will be attended with more unwholesome accompaniments than the poor habitually encounter in their wretched dwellings. And danger brings little fear to those for whom life presents a cheerless prospect.

12. If the United States of North America and many of our more advanced colonies be compared with most countries in the old world, especially the less prosperous, the truth of the preceding observations will be made apparent. As a general rule, the less agreeable occupations are easily learned, and those which demand more time and expense in preparation are pursued, when acquired, with comparative ease and comfort. The ruder labours of the field, the trade of the scavenger and others who clean out the towns and cities, are learned with facility; but drudgery and hardship attend them all through. The artistic and intellectual skill of the higher departments of industry are acquired with difficulty; but once mastered, are followed with ease and gratification. When all are really free to adopt whatever calling they like—and it is only, as has just been explained, where comfort and education are diffused that such is the case—the time and cost of learning the more difficult pursuits are set off against the discomfort of practising the simpler but coarser occupations, and all placed much nearer in point of equality of payment than in countries less favourably circumstanced, where many are unable, even if they wished, to prepare themselves for the higher departments of trade or the learned professions, and little sensible, if at all, to the discomforts of the more disagreeable callings.

LESSON IV.

SAVINGS-BANKS AND LOAN FUNDS.

> "Go to the ant thou sluggard; consider her ways and be wise: which having no guide, overseer, or ruler, provideth her meat in the summer and gathereth her food in the harvest."

1. When a person has money not needed for immediate expenditure, there are two disadvantages in keeping it

lying by him: 1st, it produces nothing; and 2nd, there is the danger of its being lost or stolen. One or both of these it is sought to avoid by placing the money in a bank, the bankers sometimes being willing to pay interest in consideration of being allowed to use it until wanted by the owner, and, at all events, being able to satisfy him that no one can carry away the money from their strongly-guarded premises; so even though no interest be paid on the deposit, just the same as if it were at home with the owner, yet at least the advantage of safe-keeping is secured. Formerly merchants put their money for safety in the Exchequer, or Royal Treasury; but King Charles I. having abused their confidence by appropriating the money, this plan was discontinued. The practice then grew up of depositing money with goldsmiths: these traders being sure to keep their establishments well protected, for the security of the precious metals in which they habitually dealt. By degrees these goldsmiths commenced lending their customers' money to other parties, observing the bankers' rule of not lending too much at a time or for too long a period, so that at any moment they might have enough available to satisfy such as called for their deposits. And finally, some devoted themselves exclusively to the business of receiving and lending money; and thus were established those institutions now known as banks for taking deposits and advancing loans, usually called, for the sake of brevity, banks of deposits.

2. From these the poorer classes in general derived no benefit.

The expenses attending the entering down of deposits of pretty considerable sums, such as 10*l.* and upwards, giving receipts or acknowledgments for them, noting their repayment, and performing various incidental matters besides, are very insignificant compared with the amount of the money; and bankers, accordingly, are willing not only to charge nothing for keeping it, but even in some cases to pay interest to the depositor, on condition of his leaving it with them for a certain time. When the deposits made from time to time, on the contrary, are very small, such as a few pence or shillings each, the above expenses become far greater in proportion; and bankers not only cannot afford to pay interest, but even will not consent to take care of the deposits gratuitously, as the cost of management might swallow up any profit they could hope to gain by the use of the money. In like manner the expenses connected with loans of small amount are far more considerable in proportion than for those of large sums; and bankers are thus prevented from deriving remuneration by lending to the poor unless they charge them higher interest than the rich. For example, if 5*l.* were enough to remunerate a person for lending 100*l.* for a year, it is plain that one shilling each for a hundred loans of 1*l.* would not answer equally well, when we take into account that the necessary expenses in the latter case would be one hundred times greater than in the former. But until last year no more than five per cent. was allowed to be charged on loans for 10*l.*, or under, any one receiving a higher rate being exposed to punishment as guilty of the offence of *usury.**

3. The result of all this was that the humble classes had no secure and satisfactory place for depositing the small sums they might save from time to time, and were equally at a loss for some banking establishment where they might raise on fair terms such trifling loans as they occasionally required. But the certainty of finding a place of security in which to deposit their earnings, is one of the principal inducements to save; and there being none such, the poor rarely saved, or if

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* By the usury laws, (or laws against receiving money for the use of money,) the taking of any interest whatsoever was prohibited in England in the reign of Edward VI. Previously, under Henry VIII., so much as 10 per cent had been allowed; and after the inconvenience of Edward's prohibition was experienced for a while, this law was revived. The legal rate of interest was subsequently reduced from time to time, and at length, in the reign of Queen Anne, it was fixed at 5 per cent. It remained so ever since until about fifteen years ago, when the restriction was removed, except with respect to loans from 10*l.* downwards, or for any amount whatever if lent on landed security: and last year these exceptions also were abolished. So now we have no usury laws; but in most other countries they still subsist in some shape or form.

they did so, were often robbed of what they had put together. And when they wanted to borrow, few were to be found willing to lend; and those who were so, charged interest enormously high, as they required not only enough to afford a fair remuneration for the cost attending the loan, but also something to pay them for incurring the risk of breaking the usury laws. Hence, when any temporary calamity occurred, the chances were the labourer had no savings to draw upon, and could with difficulty, if at all, make use of his credit to borrow. So he and his family either suffered privation, or else were supported on charity. But charity is generally injurious to the energy and independence of the recipients; and when given, as it usually is, in the workhouse, often, unfortunately, contaminates by throwing them into the company of the most profligate and abandoned of their class.

4. Nor is this all. The want of a secure place for depositing savings not only exposes the poor to privation and contamination in periods of distress by preventing accumulation, but also, and in the same manner, it takes away, on ordinary occasions, a powerful stimulus to industry and good conduct; for the man who does not save, either earns less or spends more than he who does, his extra expenditure, unhappily, being usually turned towards dissipation in public-houses or elsewhere.

This shows the importance of supplying the poor with saving-banks of some description or other, and leads us to consider with interest and attention the efforts which have hitherto been made to meet this requirement, the results which have followed, and the remedies, if any, which the present condition of such institutions renders necessary or desirable.

5. Rise and Progress of Savings-Banks.—The first notice we meet with of an attempt to assist the poor by engaging them to save such little sums as they could, to support themselves in hard times, was made in 1799 by the Rev. Joseph Smith, of Wendover. He circulated proposals, in conjunction with two of his parishioners, in which they offered to receive from any

inhabitant of the parish small sums, from twopence upwards, every week during the summer months, to keep an exact account of the money deposited, and to repay at Christmas to each individual the amount of his deposit, with one-third of that sum in addition, as a bounty on his economy. The next endeavours of the kind was made five years afterwards by Mrs. Priscilla Wakefield, who opened a bank at Tottenham, the managers of which agreed to receive small sums from the poorer classes and pay them a certain rate of interest on their deposits. But it was in 1810 that the system of Charitable Savings Banks seems to have been fairly set in motion. In that year the Parish Bank Friendly Society of Ruthwell was formed by Mr. Henry Duncan, who published an account of the institution, with a view to promote the establishment of others elsewhere. This was the first savings-bank, regularly and minutely organized, which was brought before the public; and it is doubtless owing to the successful example thus set, that in the course of a few years there were seventy savings-banks established in England, four in Wales, and four in Ireland.

6. In 1817, Government stepped forward to assist these charitable institutions, which had hitherto been such a source of loss to their conductors as to prevent them from becoming general. Not only had the conductors, whether trustees or managers, defrayed the cost of carrying on the business of the banks, but also, not unfrequently, they were unable to invest the money intrusted to them so as to get the interest which they themselves were paying to the depositors. To afford relief against this, Government undertook, on condition of the deposits being handed over to certain commissioners of their own, to guarantee the payment of a fixed rate of interest, without putting the conductors to the trouble of investment, and to return the principal to each depositor when required. A portion of the interest those who managed the bank were allowed to retain, to pay the salaries of the clerks and others they employed. Certain rules and regulations were prescribed by parliament to be observed in the management of all savings-

banks; but in some respects each was allowed to act for itself. The following are taken from the rules of one of the principal banks, and may serve as a pretty fair specimen of those generally adopted:—

"Deposits from 1*s*. to 30*l*. received from any depositor within the year."

"No one to be allowed to deposit more than 150*l*." (That is, so soon as the principal of the sums deposited, over and above whatever the depositor might have withdrawn, amounted to 150*l*., no more would be received from him.) "When the interest on the deposits brought them up to 200*l*., no further interest allowed."

7. The object of these rules may easily be understood. Deposits so low as 1*s*. were taken, as it was thought that many of the poor might find difficulty in making up a larger sum at once; and if they attempted to keep it themselves until more could be added, the chances were they would be unable to resist the temptation of spending it. And no smaller deposits than 1*s*. were received, as it was believed that were such to be taken, the relative cost of management, as explained before, would become too great. In New York, however, there is a charitable savings-bank where sums so low as sixpence are taken, and there not long since the deposits amounted to more than 10,000*l*. On the other hand, the reason why the deposits were not suffered to exceed a certain limit was, that without such a restriction persons not really poor might take advantage of the favourable terms meant solely to assist those who were so. The self-supporting banks, which are open to all, either allow no interest on deposits, or else much less than the charitable savings-banks. It is, in fact, no wonder that bankers who pay for all the work of managing their concerns, and yet expect to make profit, cannot afford so much interest on the money left with them, as those who get much of their work done gratuitously, and, besides, are not allowed to gain anything for themselves.

8. By a return published in 1832, the total amount of deposits in all the savings-banks in the United Kingdom was nearly 15,000,000*l*.; the number of depositors,

half a million; and the sum, on an average, held by each, 30*l.* Each of the depositors, probably, on an average likewise, had not less than three persons depending on him; and thus we may conclude that about two millions of the poorer classes were placed beyond any immediate danger of want by the savings laid by in the banks. Ten years later, the total amount of deposits and number of the depositers had doubled; and as the population of the country had not increased nearly so much within the same interval, a gratifying test was afforded of a considerable improvement in their condition.

9. Charitable loan-funds, as well as savings-banks, have been established for the relief of the poor. But they have seldom turned out successful. In fact, though charity may make a safe guardian for the money of the poor, it is likely to make an indifferent lender. In proportion to the distress of the applicant is the desire to relieve excited; but those most subject to distress are often excessively dishonest, and find it difficult to induce persons of substance to give security for their repayment of what they borrow. They then offer as security persons like themselves, poor and dishonest; and the common result is that the loan if made is never recovered. From this and other causes, charitable loan-funds often go on badly, and are not very generally to be met with; and the poor in their difficulties must usually rely on the pawnbroker, who can lend with perfect safety, as, if the money he advances be not repaid within a certain time, he sells the pledge left in his shop and repays himself.

10. It is worth inquiring if it be not possible for savings-banks to be self-supporting, and capable of existing without the aid of charitable managers or state officials. The expense of managing small deposits, it is true, is considerable, but much of the cost of banking of every kind in England and Ireland results from imperfections in the law. Were these removed, it might be quite possible for savings-banks to be conducted on the self-supporting system. In Scotland, where the laws in this respect are far better, charitable savings-

banks have never made much progress, and the humbler classes have deposits to a great amount in banks of the ordinary description. Such in time may come to pass in the rest of the United Kingdom; but as changes of such a nature are rarely brought about, except gradually, it is essential for the present to reform the existing savings-banks; and this, it may be hoped, can be done without much difficulty in the manner before suggested.

R. H. Walsh.

Chemistry.

BY EDWARD FRANKLAND.

LESSON I.

CHEMICAL NOMENCLATURE.

1. The study of every science necessitates an acquaintance with the system of names, and peculiar modes of expression, which have been found most convenient to denote the materials, and to describe the phenomena, which form its objects. Such system of names and modes of expression, together with their classification, form, as it were, the groundwork of the language of every science, upon the right employment of which depend the clearness and strict accuracy of scientific definition: few subjects connected with such a study are consequently of more importance to the pupil, than nomenclature and classification, and to these therefore we will now devote some attention.

2. The nomenclature of a science ought to be distinguished for its clearness and simplicity, but it is by no means easy to secure these conditions in a science like chemistry, where the rapid progress of discovery necessitates the continual addition of new names, and the frequent alteration of old ones. The name of a chemical substance should not only identify and individualise that substance, but it should also express the composition of the body, if a compound, to which it is applied. The first of these conditions is readily at-

tained, but the second is much more difficult to secure, inasmuch as our ideas of the composition of chemical compounds—the mode in which they are built up as it were—require frequent modification. It has therefore frequently happened that at different periods of the history of the science, the same substance has received different names; the compound of chlorine and hydrogen, for instance, obtained by distilling common salt with sulphuric acid, first received the name *spirit of salt* at an early period, when it was supposed that there existed a certain analogy between the constitution of chemical compounds and the connection of the human body with the soul or spirit; at the same period the analogous names *spirit of wine*, *spirit of hartshorn*, *spirit of nitre*, &c., were invented.

Subsequently, when certain notions regarding the materiality and functions of heat—the so-called phlogiston thereof—occupied the minds of chemists, spirit of salt became *dephlogisticated marine acid*, that is, acid of sea-salt deprived of its phlogiston, or material principle of heat. At a later period, when oxygen was regarded as the source of acidity, the name became *oxymuriatic acid;* and finally when Davy demonstrated the elementary character of chlorine, and the true composition of its compound with hydrogen, this body received its present title, *hydrochloric acid.* These repeated changes would not, however, materially inconvenience the young student, if the new names only of such bodies were employed; but unfortunately the old ones are also frequently made use of, and it is by no means uncommon, even at the present day, to hear the names spirit of salt and muriatic acid applied to hydrochloric acid: on the other hand, the continued use of these old names is perhaps to a certain extent serviceable, in recalling to mind the views of the bygone periods of the science, and thus contributing to facilitate the acquisition of knowledge in historic chemistry. With the exception of these drawbacks, however, the present system of chemical nomenclature is sufficiently simple, and its thorough comprehension presents no formidable difficulties.

3. The number of elements, or substances incapable of being decomposed, at present known to chemists, is sixty-two, and these have received the following names :—

Oxygen	O	Cadmium	Cd
Hydrogen	H	Cobalt	Co
Nitrogen	N	Nickel	Ni
Carbon	C	Potassium (Kalium)	K
Boron	B	Sodium (Natrium)	Na
Silicon	Si	Lithium	Li
Sulphur	S	Barium	Ba
Selenium	Se	Strontium	Sr
Phosphorus	P	Calcium	Ca
Chlorine	Cl	Magnesium	Mg
Bromine	Br	Aluminium	Al
Iodine	I	Glucinum	G
Fluorine	F	Zirconium	Zr
Thorium	Th	Tantalum	Ta
Yttrium	Y	Terbium	Te
Didymium	D	Erbium	Er
Cerium	Ce	Chromium	Cr
Niobium	Nb	Vanadium	V
Pelopium	Pe	Uranium	U
Lanthanum	Ln	Gold (Aurum)	Au
Manganese	Mn	Iridium	Ir
Iron (Ferrum)	Fe	Osmium	Os
Copper (Cuprum)	Cu	Platinum	Pt
Titanium	Ti	Tin (Stannum)	Sn
Tungsten (Wolframium)	W	Lead (Plumbum)	Pb
Molybdanum	Mo	Bismuth	Bi
Tellurium	Te	Silver (Argentum)	Ag
Arsenic	As	Palladium	Pd
Antimony (Stibium)	Sb	Rhodium	R
Mercury (Hydrargyrum)	Hg	Ruthenium	Ru
Zinc	Zn	Ilmenium	Il

These elementary substances have been long divided into two great classes—*metals* and *metalloids*, or metallic and non-metallic elements; the first thirteen in the above list being metalloids, whilst the remaining members on the list are metals: but although this division is on many accounts convenient, yet it has strictly no existence in nature; for we shall find that whilst arsenic, antimony, and tellurium, are in their physical properties true metals, they incontestably belong in their chemical relations to the metalloids.

4. The names of these bodies can scarcely be said to have been given according to any rule; many of them

are derived from the most prominent property of the bodies themselves, whilst others have mythological origin. An attempt has been made to distinguish the metals by the termination *um*, as potassium, sodium, &c.; but the common metals, such as gold, copper, iron, &c., still retain their original names; and one substance, selenium, which, at the time of its discovery, was regarded as a metal, has had no change made in its name, although further research has divested it of all metallic attributes. An important group of the metalloids—chlorine, bromine, iodine, and fluorine—have received the termination *ine;* three are distinguished by the terminal syllable *on*, viz., carbon, silicon, and boron; and three others have *gen* for their final syllable, viz., oxygen, hydrogen, and nitrogen, these last names being derived from Greek words denoting the property, possessed by these elements, of generating respectively, acid, water, and nitre.

5. When two elementary bodies unite together, they form a chemical compound of the first order, to which the name *binary compound* has been applied. A large number of such binary compounds containing oxygen are either *acids* or *bases*. The term acid was originally applied to all substances possessing a sour taste like vinegar; but analogy has necessitated the application of the same name to a large number of compounds, which have not this property, and therefore an acid may now be better defined as a body capable of uniting with a base to form a *salt;* a base being, in like manner, a substance capable of uniting with an acid and forming a salt, of which it is the basis or foundation. When an acid contains oxygen, its name is generally formed by adding the termination *ic*, either to the name of the element with which the oxygen is united, or to an abbreviation of that name: thus sulphur forms with oxygen, sulphuric acid, nitrogen, nitric acid, and phosphorus, phosphoric acid. But it frequently happens that the same element forms two acids with oxygen, and when this occurs, the acid containing the largest amount of oxgyen receives the terminal syllable *ic*, whilst that containing least oxygen is made to end in

ous. Thus we have sulphurous acid, nitrous acid, and phosphorous acid, each containing a smaller proportion of oxygen than that requisite to form respectively sulphuric, nitric, and phosphoric acids. In some instances, however, the same element forms more than two acids with oxygen, in which case the two Greek words *hypo*, under, and *hyper*, over, are prefixed to the name of the acid. Thus an acid of sulphur, containing less oxygen than sulphurous acid, is termed hyposulphurous acid, and another acid of the same element, containing more oxygen than the sulphurous acid and less than the sulphuric, might be named either hypersulphurous acid, or hyposulphuric acid; but the latter term has been universally adopted. The Latin prefix *per* is frequently substituted for the Greek *hyper;* thus in the case of chlorine, which forms four acids with oxygen, viz., *hypochlorous* acid, *ochlorous* acid, *chloric* acid, and *hyperchloric* acid, the latter is generally named *perchloric* acid: but *per* can only be used as a prefix to the acid containing the largest proportion of oxygen.

6. Some acids do not contain oxygen amongst their constituents; but, instead of this element, contain either sulphur or hydrogen united with some other element. This peculiarity of composition is expressed in their nomenclature, by the prefixes *sulpho* or *sulph*, and *hydro* or *hydr;* thus *sulpharsenic* and *sulphostannic* acid denote acids composed respectively of sulphur and arsenic, and sulphur and tin; whilst the names *hydrochloric* acid, and *hydriotic* acid, are given to acids composed, the first of hydrogen and chlorine, and the second of iodine and hydrogen. The terminals *ic* and *ous* are also applied to these acids, in exactly the same manner as to the oxygen acids: thus we have *sulpharsenious* and *sulpharsenic* acids; the latter containing a larger proportion of sulphur than the former; but the application of the second of these terminals has not hitherto been found necessary in the case of hydrogen acids, since no element has yet been observed to form more than one acid with hydrogen.

7. When the compound of an element with oxygen is not an acid, it is termed an *oxide* of the element with

which the oxygen is combined. Thus we have *oxide of copper*, *oxide of zinc*, *oxide of iron*, *oxide of tin*, &c., which names denote respectively, the compounds of the metals, copper, zinc, and tin, with oxygen. As in the case of acids, the same element also frequently forms more than one oxide, and then Greek and Latin prefixes are employed to distinguish them. Thus *protoxide* and *deutoxide* signify the first and second oxides of an element—as *protoxide of manganese*, *deutoxide of manganese*: sometimes *binoxide* is used in the place of deutoxide; as *binoxide of manganese*, *binoxide of nitrogen*. The prefix *per* signifies the oxide containing the largest proportion of oxygen; thus *peroxide of lead*, and *peroxide of mercury*, represent respectively those oxides of lead and mercury, containing the maximum amount of oxygen. *Suboxide* is a term applied to a compound containing less oxygen than a protoxide; thus we have *suboxide of lead*, *suboxide of copper*, &c. The prefix *sesqui*, is applied to those oxides which consist of a combination of oxygen with some other element, in the proportion of one and a half of the former to one of the latter—as *sesquioxide of iron*: the meaning of the prefix sesqui cannot, however, be fully understood, until the laws of chemical equivalents have been discussed.

8. The remaining binary compounds, which are neither acids nor bases, are named upon much the same plan as the latter: thus the compounds of chlorine are termed *chlorides*, and those of sulphur *sulphides*—as *chloride of iron*, *sulphide of lead*, &c.; but the nomenclature of a considerable number of these compounds is unnecessarily complicated by the retention of the termination *uret*, which was formerly applied to all these compounds; sulphide of lead, for instance, is frequently written sulphuret of lead; and although this latter terminal is being gradually displaced by the uniform *ide*, yet it is still employed by so many chemists, that it cannot be disregarded in a description of the present system of nonmenclature; I have therefore introduced it in the following table wherever its use is still so retained:—

Chlorine	forms	Chlorides		
Bromine	„	Bromides		
Iodine	„	Iodides		
Fluorine	„	Fluorides		
Sulphur	„	Sulphides	or	Sulphurets.
Selenium	„	Selenides	„	Seleniurets.
Tellurium	„	Tellurides	„	Tellurets.
Carbon	„	Carbides	„	Carburets.
Hydrogen	„	Hydrides	„	Hydrurets.
Nitrogen	„	Nitrides	„	Nitrurets.
Phosphorus	„	Phosphides	„	Phosphurets.
Arsenic	„	Arsenides	„	Arsenurets.
Antimony	„	Antimonides	„	Antimonurets.

9. The names generally given to the compounds of hydrogen with sulphur, selenium, tellurium, carbon, phosphorus, arsenic, and antimony, are to a certain extent exceptions to the plan of the above table; thus a compound of sulphur and hydrogen is frequently termed *sulphuretted hydrogen*, instead of sulphide of hydrogen, and, in the same way,

Selenium	and	Hydrogen	form	Selenuretted hydrogen.
Tellurium	„	„	„	Telluretted hydrogen.
Carbon	„	„	„	Carburetted hydrogen.
Phosphorus	„	„	„	Phosphuretted hydrogen.
Arsenic	„	„	„	Arsenuretted hydrogen.
Antinomy	„	„	„	Antimonuretted hydrogen.

When the above elements unite in more than one proportion with each other, or with any other element, the separate compounds are distinguished by the same Greek or Latin prefixes, as those employed in naming the oxides: thus we have *protosulphide* and *bisulphide of iron*, *terchloride* and *pentachloride of antimony*, &c.

10. In cases where the elements, contained in the first of the two tables just given, unite with each other, the name is determined by the position of the two elements in that table, those elements being arranged in accordance with certain important points in their chemical character, the element standing highest in the table is mentioned first: thus we call a compound of chlorine and bromine, chloride of bromine, and not bromine of chlorine; and, according to the same rule, we say phosphide of arsenic and sulphide of selenium, instead of arsenide of phosphorus and selenide of sulphur.

11. The only other binary compounds, requiring notice here, are those of the metals with each other, such

compounds are termed *alloys*. Thus brass is an alloy of zinc and copper, and bronze is an alloy of tin and copper. The only exceptions to this rule are mercury, whose compounds are termed *amalgams*, and those metals which have already been noticed as resembling the metalloids, in their chemical character. The compounds of these elements with other metals are generally named like binary compounds of metals and metalloids: thus we name a compound of zinc and arsenic, *arsenuret of zinc*, in preference to an *alloy of zinc and arsenic*.

LESSON II.

CHEMICAL NOMENCLATURE—*continued.*

1. The union of two binary compounds produces a *secondary compound*. Secondary compounds are generally salts, although a large number of salts, such as the chlorides, bromides, iodides, and fluorides, of the metals, are binary compounds. Secondary salts consist of an acid and a base, and their nomenclature is very simple, the base giving the general name to the salt: thus we say, a salt of potash, a salt of lime, or a salt of magnesia; the distinctive name of each salt of the same base being formed by changing the final *ic* of the acid into *ate*, and placing it before the name of the base: thus the salt, formed by the union of sulphuric acid with potash, is termed *sulphate of potash;* that of lime with nitric acid, *nitrate of lime*, &c. When the name of the acid ends in *ous*, the terminal is changed into *ite;* thus *sulphite of soda*, and *hyposulphite of lime*, signify respectively compounds of sulphurous acid with soda, and hyposulphurous acids with lime.

2. There is one circumstance connected with the nomenclature of salts, which frequently leads the learner astray; it is the suppression of the words *oxide of*, when these words form a part of the name of the base. Thus, instead of saying *sulphate of oxide of zinc* we say simply *sulphate of zinc*, a name which certainly has the advantage of brevity, but which is very liable to convey the erroneous idea, that the compound consists of sulphuric acid and *zinc*, whereas it is in reality com-

posed of sulphuric acid and *oxide of zinc*. As the salts, which suffer this elision, are far more numerous than those which do not, it is of great importance to bear this circumstance in mind.

3. When a metal forms several compounds with oxygen, it sometimes happens that each oxide, by uniting with acids, forms a separate class of salts, such classes are then distinguished from each other by the prefixes *proto*, *sesqui*, *per*, according as the base is a protoxide, a sesquioxide, or a peroxide. Thus *protosulphate of iron* and *sesquisulphate of iron* signify, the one a compound of sulphuric acid with *protoxide of iron*, and the other a compound of the same acid with *sesquioxide of iron;* and as the sesquioxide of iron is also the peroxide of that metal, the sesquisulphate is frequently termed the *persulphate.* Such salts are also frequently assigned to their respective classes by the general expressions *protosalts*, *sesquisalts*, *deutosalts*, &c. Just as the proportion of metal and oxygen can vary in bases, so can the relative proportions of acid and base in salts. Provision is made for this, by using the Latin prefixes *bi*, *ter*, &c., to denote the proportion of acid; as *bichromate of potash*, *terchromate of potash*, &c.; and the Greek prefixes *di*, *tri*, &c., to indicate the proportion of base; as *dichromate of lead*, *trisnitrate of bismuth*, &c. The proportion of base in salts is also frequently expressed by the terms *monobasic*, *bibasic*, *tribasic*, *quadrobasic*, &c., signifying salts containing one, two, three, four, &c. proportions of base; thus we say *bibasic* sulphate of zinc, *quadrobasic* sulphate of copper, &c.

4. In addition to secondary salts, we have also several other species of secondary compounds. Thus oxides combining with chlorides, bromides, iodides, &c., form such compounds, termed *oxychlorides*, *oxybromides*, *oxyiodides*, &c.—as *oxychloride of lead*, *oxybromide of copper*, *oxyiodide of zinc*, &c. Sometimes two chlorides or two iodides, &c., unite, and produce *double chlorides*, *double iodides*, &c.: thus we have the *double chloride of platinum and potassium*, the *double iodide of gold and potassium*, &c.

5. An important class of secondary compounds is formed by the union of water with binary compounds; such bodies are termed *hydrates*—as *hydrate of potash*, *terhydrate of alumina*, &c. Sometimes the word *hydrated* is employed—as *hydrated oxide of chrominm*, *hydrated sulphuric acid*, &c.

6. The combination of two secondary compounds produces a *ternary compound*. Ternary compounds are generally double salts, whose nomenclature is so obvious as scarcely to require explanation. Sulphate of copper, for instance, unites with sulphate of potash, to form the *double sulphate of copper and potash*. Sesquisulphate of alumina and sulphate of potash form the so-called *dry alum*, which is consequently a double sulphate of alumina and potash.

7. A *quaternary compound* is formed by the union of three secondary compounds, one of which is usually water: thus dry alum, uniting with water, produces *crystallized alum*; but these compounds, as well as other still rarer ones of more complex structure, need no further notice here, as their nomenclature involves no new feature.

8. SYMBOLICAL NOMENCLATURE.—In the list of elementary bodies already given, one or two letters will be observed attached to each name; these are the symbols used by chemists, to denote the element to which each is attached: thus O signifies oxygen, H hydrogen, Cr chromium, &c. These symbols greatly simplify, and render expressive, chemical nomenclature: they not only serve a highly-useful purpose as abbreviations, but are also invaluable, as a means of conveying, with clearness and accuracy, our ideas of the nature of chemical compounds in general: and since their introduction into the science, chemical language has attained an exactitude and definiteness, which would have been impossible without the aid of these symbolical expressions.

9. Each symbol is generally the initial letter of the Latin name of the element to which it is attached; but as the names of several of the elements frequently begin with the same letter, it is necessary to distinguish them

by the use of a second letter in small type, which is either the second letter of the word, or some other letter which is prominently heard in its pronunciation: thus carbon, cadmium, cobalt, and cerium, all begin with the same letter; but they are distinguished by the symbols C, Cd, Co, and Ce. In the use of the single letters, the non-metallic elements have the preference: thus oxygen, hydrogen, nitrogen, sulphur, phosphorus, boron, carbon, iodine, and fluorine, are expressed by the single letters O, H, N, S, P, B, C, I, and F; whilst the metals osmium, mercury, nickel, strontium, platinum, bismuth, cobalt, iridium, and iron are symbolized by two letters each: thus Os, Hg (hydrargyum), Ni, Pt, Bi, Co, Ir, and Fe (ferrum). In the selection of the single letter for other cases, preference is given to the most important element: thus sulphur, selenium, and silicon, are all non-metallic elements, beginning with the same letter, but sulphur, being the most important, the single letter S is assigned to it; whilst selenium and silicon are denoted respectively by Se and Si.

10. The symbols of binary compounds are produced by simply joining together the symbols of their constituents: thus Zn O represents oxide of zinc, H A hydrochloric acid, H Br hydrobromic acid, &c. In writing the symbols of secondary compounds, it is usual to separate the two binary compounds by a comma: thus hydrate of potash is written K O, H O, which signifies, that the potash and water are held together by a weaker affinity, than that which retains in combination either the oxygen and potassium, or the oxygen and hydrogen. In the case of ternary compounds, a further relative difference in affinity is expressed by the use of the sign +: thus the double sulphate of copper and potash is written $K\ O, S\ O_3 +$ CuO, SO_3. The symbol of this last compound exhibits also the simple mode, by which the relative proportions of elements in a compound are expressed, the symbol for sulphuric acid (SO_3) showing, that this acid consists of one proportion of sulphur, combined with three proportions of oxygen, the small figure $_3$ after e symbol O referring to that letter only; and in all

cases, where small figures are thus attached to symbols, they affect only the elementary symbol immediately preceding them: thus NO_2, NO_3, NO_4, and NO_5 signify respectively compounds of nitrogen with 2, 3, 4, and 5 proportions of oxygen. When it is desired to express two or more proportions of a binary compound, large figures are prefixed to a symbol: thus 2 KO signifies two proportions of potash, 6 HO six proportions of water, &c., the figure here affecting both symbols; in fact large figures thus placed affect all the letters following them up to the next comma or sign $+$; thus $2\ NH_4O,\ PO_5$ signifies a compound, consisting, on the one hand, of two proportions of nitrogen, eight of hydrogen, and two of oxygen, and on the other, of one proportion of phosphorus, and five proportions of oxygen. A large figure placed before, or a small one after a parenthesis, affects all the symbols within the parenthesis: thus $6\ (KO,\ SO_3)$, or $(KO,\ SO_3)_6$, signifies six proportions of sulphate of potash. But as these numerical symbols involve the laws of chemical equivalents and multiple proportions, it is impossible fully to understand either their use, or their meaning, until the next chapter has been studied.

11. Before concluding the subject of chemical nomenclature, we will here notice a few technical terms which, being applied to certain chemical phenomena of frequent occurrence, render it necessary that the young student should thoroughly understood their meaning. *Reagent* is a name applied to any substance which is employed for the detection of any other material in chemical analysis; it is synonymous with the word *test*. *Digestion* is a term applied in chemistry to the prolonged contact of two or more bodies, one at least of which is liquid. When a solid body is separated from a liquid or gas, in consequence of some chemical change, the phenomenon is termed *precipitation;* because the solid, owing to its being usually specifically heavier than the liquid or gas, from which it separates, is *precipitated*, or thrown down to the bottom of the vessel in which the process takes place: a solid thus deposited is termed a *precipitate*. *Crystallization* is closely connected with precipitation,

and consists in the deposition of a solid from a liquid or gas in a more or less regular geometrical form, the separate particles or pieces of which are termed *crystals*. Crystallization occasionally, though very rarely, takes place in solids. Crystallization also differs from precipitation, in being generally unaccompanied by chemical change; solid matter thus formed is said to be *crystalline*, or *crystallized*, in contradistinction to solids, which possess no crystalline structure, and which are said to be *amorphous*. When any matter, whether solid, liquid, or gaseous, is dissolved in a liquid, the former is said to be in *solution*, and the latter is termed the *solvent*. A solvent can generally only dissolve certain fixed quantities, and when it has taken up the largest amount possible of any substance, it is said to be *saturated*. A substance is said to be *acid*, or to have an *acid reaction*, when it possesses the property of changing the blue colour of litmus to red, all bodies having an acid or sour taste possessing this property. In like manner a body which turns the yellow colour of turmeric, brown, is said to be *alkaline*, or to have an *alkaline reaction*, because this property is characteristic of the alkalies, potash, soda, and ammonia. Those substances which possess neither of these reactions are said to be *neutral*, or to *react neutral*.

LESSON III.

CHEMICAL CLASSIFICATION.

1. **Chemical Equivalents.** — One of the most remarkable circumstances connected with chemical affinity is the invariable and definite composition of chemical compounds. When two or more elements unite chemically, they always do so in certain fixed and definite proportions, and every chemical compound always contains the same elements, united in exactly the same proportions, however that compound may have been formed. Thus, water invariably consists of eight parts by weight of oxygen, and one part by weight of hydrogen, no matter whether that water exist naturally, in the form of ice, snow, rain, or steam, or be produced artificially by the direct union of its elements. If we examine various spe-

cimens of common salt, obtained from the saltbeds of Cheshire, the deep mines of Poland, the brine-springs of Germany and America, by the evaporation of sea-water, and by artificially combining the elements of salt, we find that every specimen has precisely the same properties, and consists of 22·97 parts of sodium, united with 35·47 parts of chlorine. Upon this law of definite combining proportions, rests the whole fabric of chemistry as an exact science; without such regularity of composition the chemical operations of analysis and synthesis, would be either incapable of execution or devoid of all value when performed. If it were possible, for instance, that common salt, with the usual properties we ascribe to this body, could exist or be produced from other elements, besides chlorine and sodium, or could consist of these elements united in different proportions, it would be impossible for us to ascertain the composition of a new sample of common salt by reference to any number of previous experiments upon other samples; and thus that accumulation of knowledge, and that strict definition so essential to the progress of a science, would be impossible. The first and most important law of chemical combination may therefore thus be expressed:

Law 1st.—*The composition and properties of compounds are fixed and invariable.*

2. The second law of chemical combination is most intimately connected with the first, and can be thus stated:

Law 2nd.—*The relative quantities in which bodies unite, or in which they replace each other in chemical compounds, may be expressed by proportional numbers.*

3. These laws are of so much importance and interest, as the fundamental basis of chemical science, that it will be necessary for us here to examine a few of the data upon which they are constructed, as well as to inform ourselves of the general nature of the methods by which the combining proportions of substances are determined.

When hydrogen gas is passed over red-hot oxide of copper, the latter is decomposed, yielding its oxygen to the former; so that, from oxide of copper and hydrogen, we have produced oxide of hydrogen (water) and metallic copper. Hydrogen has, therefore, here replaced copper in the oxide of copper. Now, if we take for our experiment exactly 100 grains of oxide of copper, we shall find that, after the action of the hydrogen is complete, there will remain 79·83 grains of metallic copper; and if we also collect, in a suitable apparatus, the water produced, it will be found to weigh exactly 22·69 grains. But as the 100 grains of oxide of copper contained only 79·83 grains of copper, it follows that the remaining 20·17 grains (100 − 79·83 = 20·17) were oxygen, which amount of oxygen must evidently have united with 2·52 grains of hydrogen, to form the 22·69 grains of water (20·17 + 2·52 = 22·69). We therefore learn from this experiment, that the relative combining proportions of copper, oxygen, and hydrogen, are respectively 79·83, 20·17, and 2·52. By carrying our experiment further, it is easy to ascertain the combining proportions of other elements: thus if, instead of acting upon the oxide of copper with hydrogen, we employ hydrochloric acid (chloride of hydrogen), then chloride of copper and water will result, and we find that the 100 grains of oxide of copper again yield 22·69 grains of water, whilst the chlorine of the hydrochloric acid unites with the copper, and forms exactly 169·04 grains of chloride of copper. Now, as this chloride of copper contains 79·83 grains of copper, it follows that 89·21 grains of chlorine (169·04 − 79·83 = 89·21) have been required by the copper, in order to produce chloride of copper, and it is also further evident, that these 89·21 grains of chlorine have been united with 2·52 grains of hydrogen in the hydrochloric acid employed; because the 22·69 grains of water, formed in the reaction, have already been proved to contain 2·52 grains of hydrogen, and we have hence a double proof that 89·21 grains of chlorine are equivalent to 79·83 grains of copper, 2·52 grains of hydrogen, and 20·17 grains of oxygen. Bearing these data in mind, we can next combine 2·52 grains of hydrogen with sulphur, and shall find that 40·57 grains of this latter element are required to form the compound sulphide of hydrogen. If we now bring this sulphide of hydrogen in contact with iodine, it is completely decomposed, the whole of the sulphur being precipitated and hydriodic acid (H I) formed; the weight of this new compound will be found to be 320·79 grains, and as it is known to contain only 2·52 grains of hydrogen, it follows that 318·27 grains (320·79 − 2·52 = 318·27) of iodine have been required to replace 40·57 grains of sulphur. Again, on treating this hydriodic acid with bromine, the iodine is expelled, and hydrobromic acid (H Br) is the result. To effect this change, it is found that exactly 196·83 grains of bromine are requisite. Finally, if the hydrobromic acid thus produced be treated with chlorine, it is also decomposed, all the bromine being separated and a quantity of hydrochloric acid, weighing 91·73 grains, produced: this is, as already shown, the exact amount of hydrochloric acid requisite to transform 100 grains of oxide of copper into chloride of copper. These experiments could of course be prosecuted so as to include the whole of the known elements; but a sufficient number of examples have already been given, to illustrate the general principles involved in such determinations. On tabulating the results, we have the following numbers, representing the combining proportions of the elements employed in the foregoing decompositions:—

Oxygen	20·17	Bromine	196·83
Hydrogen	2·52	Iodine	318·27
Sulphur	40·57	Copper	79·83
Chlorine	89·21		

4. These combining proportions are frequently termed *equivalent numbers*, or *chemical equivalents*, because the quantities of the different elements, expressed in the above table, are equivalent to each other in chemical combination; for instance, if we require 89·21 parts of chlorine to produce a certain chemical effect, we shall require, in order to produce the same effect, 196·83 parts of bromine, or 318·27 parts of iodine.

5. The absolute numerical results of these experiments are evidently quite arbitrary, for if we had commenced with a different weight of oxide of copper, although the proportion between these numbers would have remained the same, yet the numbers themselves must obviously have been totally different. So far, therefore, as

accuracy is concerned, it is a matter of indifference what numbers be adopted, if care be taken that the above proportion between them still holds good; but for the sake of convenience and uniformity in the expression of chemical results, it is expedient to fix upon some standard. Unfortunately for perfect uniformity, two such standards have been adopted; in one, hydrogen is made the starting point, and unity is assigned as its equivalent number; in the other, oxygen is taken as the standard, with 100 as its equivalent number. The former, or hydrogen scale of equivalents, is the one generally employed in this country: whilst the latter, or oxygen scale, is invariably used by continental chemists.

6. In the following table of chemical equivalents both these scales are given:—

Names of Elements.	Equivalents.		Names of Elements.	Equivalents.	
	O = 100.	H = 1.		O = 100.	H = 1.
Aluminium	171·2	13·70	Molybdenum	598·5	47·96
Antimony	1612·9	129·20	Nickel	369·7	29·62
Arsenic	937·5	75·00	Nitrogen	175·0	14·00
Barium	858·0	68·66	Osmium	1244·5	99·72
Bismuth	886·9	71·10	Oxygen	100·0	8·00
Boron	136·2	10·91	Palladium	665·9	53·36
Bromine	978·3	78·26	Phosphorus	400·3	32·00
Cadmium	696·8	55·74	Platinum	1233·5	98·84
Calcium	250·0	20·00	Potassium	487·5	39·00
Carbon	75·0	6·00	Rhodium	651·4	52·20
Cerium	574·7	46·05	Ruthenium	651·4	52·20
Chlorine	443·7	35·47	Selenium	494·6	39·63
Chromium	351·8	28·19	Silicon	266·8	21·35
Cobalt	369·0	29·57	Silver	1350·0	108·00
Copper	395·7	31·70	Sodium	287·9	22·97
Fluorine	233·8	18·74	Strontium	547·3	43·85
Glucinum	331·3	26·54	Sulphur	200·0	16·00
Gold	1229·0	98·33	Tantalum	2307·4	184·90
Hydrogen	12·5	1·00	Tellurium	801·7	64·25
Iodine	1579·5	126·40	Thorium	744·9	59·83
Iridium	1233·5	89·84	Tin	735·2	58·92
Iron	350·0	28·00	Titanium	303·6	24·33
Lanthanum	600·0	48·00	Tungsten	1183·0	94·80
Lead	1294·5	103·73	Vanadium	856·9	68·56
Lithium	80·3	6·44	Uranium	750·0	60·00
Magnesium	158·3	12·69	Yttrium	402·5	32·25
Manganese	345·9	27·72	Zinc	406·6	32·51
Mercury	1250·8	100·00	Zirconium	420·2	33·67

In the above examples, illustrating the determination of chemical equivalents, the elements named combine with each other in one proportion only. We have, however, frequently mentioned, that two elements are often capable of combining with each other in more than one proportion, and it is in the study of such compounds, that the third law of combination is developed.

7. Law 3rd.—*When one body combines with another in several proportions, the quantities of the second body, contained in the different compounds, bear to each other a very simple ratio.*

In a very large number of cases, the proportions of the second body are simple multiples of the quantity contained in the first compound: thus, in the compounds of nitrogen with oxygen it is found that—

14	parts of nitrogen unite with	8	of oxygen to form	protoxide of nitrogen.
14		16		binoxide of nitrogen.
14		24		hyponitrous acid.
14		32		nitrous acid.
14		40		nitric acid.

Here the quantities of oxygen in combination with nitrogen are to each other as 1, 2, 3, 4, &c. In other cases, the ratio is as 1, 1½, 2, &c. Thus the combinations of manganese with oxygen take place according to this ratio:—

27·72	parts of manganese unite with	8	of oxygen to form	protoxide.
27·72		12		sesquioxide.
27·72		16		peroxide.
27·72		24		manganic acid.
27·72		28		permanganic acid.

This law of multiple proportions affects not only binary, but also secondary, ternary, and quarternary compounds, thus:—

52·2	parts of chromic acid and	47·2	of potash form	neutral chromate of potash.
104·4		47.3		bichromate of potash.
156·6		47·3		terchromate of potash.

8. The combining proportions of secondary, ternary, and quarternary compounds are expressed in the fourth law of combination, which may be thus announced:—

Law 4th.—*The equivalent number of a compound is equal to the sum of the equivalent numbers of its constituents.*

Thus the combining proportion of water, which is 9, is found by adding together the equivalents of its elements, 1 and 8. The equivalent of quicklime is 28, because it consists of 1 equivalent of calcium (20), and 1 equivalent of oxygen (8). And, for the same reason, the combining proportion of hydrate of lime is 37, which is the sum of the equivalents of its constituents, lime 28 and water 9.

9. The remarkable facts, expressed by the third and fourth laws of combination, have received a very simple and beautiful explanation in the so-called *atomic theory*, which, together with the laws of combination, was developed principally by the intellectual genius of Dalton. According to this theory, all bodies are made up of a number of exceedingly small particles, termed atoms, which are absolutely indivisible by any force we can apply to them; the particles of different kinds of matter possess different weights, and probably also different sizes, and it is the relative weights of these atoms which express the combining proportions of the substances they compose. The atoms of hydrogen are, therefore, the lightest of all known atoms, inasmuch as hydrogen has the smallest equivalent number; those of oxygen are eight times heavier; those of nitrogen fourteen times heavier, &c. Taking this view of the constitution of matter, it is easy to see why substances unite chemically in definite proportions only, and also why, when more compounds than one are formed by the same element, such compounds must stand in a very simple relation to each other. Thus, when nitrogen unites with oxygen, the first compound consists of fourteen parts or one atom of nitrogen, and eight parts or one atom of oxygen; the second compound contains one atom or fourteen parts of nitrogen, and two atoms or sixteen parts of oxygen; the third contains three atoms or twenty-four parts, by weight, of oxygen, and so on. In the compounds of manganese with oxygen this theory also clearly illustrates the cause of the numerical relations of the two elements: thus, the first oxide of manganese contains one atom of manganese, and one atom of oxygen; the second, two atoms of manganese and

three atoms of oxygen; the third, one atom of manganese and two atoms of oxygen; the fourth, one atom of manganese and three atoms of oxygen; and the fifth, two atoms of manganese and seven atoms of oxygen. It must therefore follow that, in the first oxide, 27·72 parts, by weight, of manganese are united with 8 parts of oxygen; in the second, twice 27·72 = 55·44 parts of manganese, with three times 8 = 24 parts of oxygen; in the third, 27·72 parts of manganese, with twice 8 = 16 parts of oxygen; in the fourth, 27·72 parts of manganese, with three times 8 = 24 parts of oxygen; and in the fifth, twice 27·72 = 55·44 parts of manganese are combined with seven times 8 = 56 parts of oxygen. Thus the laws of combination are beautifully elucidated by this theory, the very simplicity of which is strong evidence of its truth; nevertheless, it must be borne in mind, that the laws of combination rest upon incontrovertible facts, and, as regards their soundness, are altogether unconnected with any theoretical considerations whatever.

10. We have hitherto considered only the relative weights in which bodies combine chemically, but if we also examine into the volumes in which those substances unite, which either exist as gases, or can be converted into vapours, we find even a still more simple relation amongst these combining volumes. If we take equivalent quantities by weight of hydrogen, nitrogen, chlorine, iodine, and bromine, and compare the volumes which these elements occupy in the gaseous condition, under the same temperature and pressure, we find that such equivalent weights of these elements occupy exactly the same volume: thus 1 grain of hydrogen, 14 grains of nitrogen, and 35·47 grains of chlorine, occupy precisely the same space. Again, equal volumes of oxygen and the vapours of phosphorus and arsenic, contain equivalent weights of these elements; although the volumes are only one-half of those just given: if, for instance, a certain volume of oxygen weighs 8 grains, then the same volume of phosphorus and arsenic vapour will weigh, respectively, 32 and 75 grains. It hence follows that when these bodies unite chemically, they do

so in volumes which bear a very simple relation to each other: thus two volumes of hydrogen and one volume of oxygen unite to form water; two volumes of nitrogen and one volume of oxygen form nitrous oxide; two volumes of nitrogen and two volumes of oxygen form binoxide of nitrogen; two volumes of nitrogen and three of oxygen hyponitrous acid; two of nitrogen and four of oxygen, nitrous acid; and two of nitrogen and five of oxygen form nitric acid. The same simple relation of combining volumes also holds good in the union of compounds.

11. These laws, relative to the atomic combination of substances, render still more evident the great advantages of symbolical nomenclature, which is made the means of conveying to the mind, not only the qualitative composition of chemical compounds, but also their quantitative constitution. Thus the symbol HO, not only signifies a compound of hydrogen and oxygen, but it likewise indicates, that that compound consists of one part by weight of hydrogen and eight parts by weight of oxygen; whilst HO_2, in the same manner, signifies a compound of one part of hydrogen and sixteen parts of oxygen. Symbolical nomenclature, therefore, furnishes an exact and simple mode of expressing the law of multiple proportions.—**Edward Frankland.**

Mechanics.

BY EDWARD PURCELL.

LESSON I.

DIRECTION AND AMOUNT OF FORCES.

1. We have already seen that the whole purpose of machinery is to regulate the action of a force, by altering either its direction or the velocity it produces. The object of the present chapter is to show how this end is accomplished in a number of simple machines, in order
we may be better able to trace hereafter the mode
on of more complicated contrivances. Previous to

this, however, we must make a few remarks upon the direction and amount of forces, and the manner in which these can be represented.

2. The tendency of any single force acting upon a body is to produce motion in a straight line; and the line of direction in which the motion would result if allowed to take place is called the *direction* of the force.

It is true that we scarcely ever see a body in motion under the influence of only a single force, because the natural forces, and particularly gravitation, are in incessant operation, in addition to any force that man may apply; we have, therefore, few opportunities for observing what the effect of one force would be. Still in the descent of a falling body under the exhausted receiver of an air-pump, we have a perfect instance of rectilinear motion; and a round ball rolled over a smooth even surface, though acted upon by gravity, the resistance of the air and friction, in addition to the impulse given to it by the hand, moves in the direction of the impelling force. The shape, size, and weight of the body acted upon also materially influence its motion, so that, for greater simplicity, we shall at present suppose the body to be represented by its centre of gravity alone, or by a *material point*, and afterwards consider how its mass and form are to be taken into account.

3. The straight line which indicates the direction of a force may be made to represent its relative amount, compared with any standard we assume as a unit. Thus, suppose we agree that a length, equal to one-tenth of an inch, shall stand as an arbitrary symbol for the force able to raise one pound to a height of one foot, then two-tenths of an inch will stand for a force of double this amount, three-tenths for one three times as great, &c. We thus find that by means of a scale *forces can be geometrically exhibited, in direction and general amount, by straight lines.* This fact we shall find of the greatest use in our inquiries.

Further, having our line of direction, we may mark off the length representing the amount of force, *anywhere* in this line that suits our convenience in considering a problem. The length of a rope, for instance, can make no difference in the weight suspended from it, nor that of a rod in the force with which we can push a ball if rod and rope are supposed rigid and devoid of weight.

In using lines to represent forces, we may, to get a clear, comparative estimate, suppose the exertion of each force to be made within the same time and against the same amount of resistance, and the lengths will then show the distance through which each has caused motion.

4. Composition of Forces.—When any number of forces are applied to a material point, *each acts as though the others had no existence*, for to suppose the contrary—that they in any way adapted themselves to each other—would be to ascribe to a blind impulse the faculties of reason. The *result* of their application, it is true, varies with the number and directions of the forces egaged; but we can calculate this result only by considering each force to be independent in its action, or by supposing the forces to act in succession.

If forces act in the same direction, it is manifest that the effect of each must tend to increase that of the others, and the total force will be represented by their *sum;* if they act in exactly opposite directions, some will tend to counteract the efforts of the others, and the result will be their *difference*, and in the direction of those which together have most power.

Thus if two or more boys pull in the same direction, the effort they make will be the sum of what each could do separately; if, for instance, one could pull 40 lbs., another 50 lbs., and another 60 lbs., the three together could pull 150 lbs. If some are pulling one way and some another, for instance, the boy of 60 lbs. strength pulling against the two others, then we get a pull of $40+50-60=30$ lbs. in the direction of the two weaker boys; of course, if the opposite parties were of equal strength, no motion could take place, and so equal and opposite forces are said to destroy each other.

5. If instead of being in the same line of direction acting either together or in opposition, the forces are applied in different directions, inclined at various angles to each other, it becomes a little more difficult to find

the result. Let us first suppose *two* forces, represented in magnitude and direction by the lines P F and P S, (fig. 1) to be applied to the material point P. As we have shown that each acts independently, the final result will not be altered by supposing that they act in *succession*. In this case the force P S would carry the point to S, and if we then applied at S the force P F, it would carry the point to R; the *result*, therefore, is the same as if we had applied to P in place of the two forces P S and P F, a single force represented in magnitude and direction by P R: this, therefore, is called the *resultant* of the two forces, and is manifestly the diagonal of the parallelogram P S R F. Hence we arrive at this most important conclusion:—

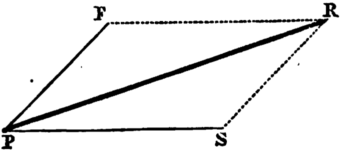

Fig. 1.

If two forces act together in different directions on a material point, the result is the same as would be produced by a single force represented in direction and amount by the diagonal of a parallelogram, whose sides represent the amount and direction of the two forces.

6. We have been led to this proposition, well known as the *Parallelogram of Forces*, by the general consideration of the independent action of forces, and the consequent possibility of considering them as acting in succession. Although it is a problem of such vital importance, as the basis of mechanical reasoning, that all the resources of mathematical skill have been employed in supplying a rigid demonstration of its truth, it must be sufficient for our present purpose to inquire, *is it a fact?* If two forces act on a point, can they be represented in the manner in which we have concluded they can?

The following simple experiment will be sufficient to exhibit its truth. Let A and B (fig. 2) be two small rollers fixed by horizontal axes to a black board placed vertically. They must be at equal distances from the board and exactly parallel to it. From the ends of a silk cord passing over the two rollers, suspend unequal weights *w* and *w'*, and at a point between the two rollers fasten to the cord another silk line, and suspend from it a weight W. The point P will then be acted upon by two forces acting in the directions P A, P B, and P W, and after a time will come to rest. Then produce W P upwards in PA, take P *t* to represent according to any given scale the lbs. in W, draw *t s* parallel to P B and complete the parallelogram P *t s n*. On measuring by scale it will now be found that P *n* represents the lbs. in *w'* and P *s* those in W. The efforts of *w* and *w'* are, it thus appears, destroyed by a force equal to *s* P, they must therefore have a resultant equal to this in amount and direction, but acting upwards instead of down, that is, their resultant *must be P s*, the diagonal of the parallelogram.

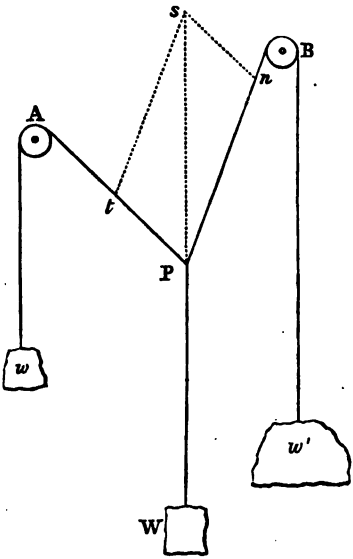

Fig. 2.

Knowing how the resultant of two forces is determined, we can find that of any number by combining first two, then their resultant with a third, and this result with a fourth, &c.; the diagonal of the last parallelogram will represent the resultant in amount and direction.

7. Resolution of Forces.—As we can represent the resultant of a number of forces by a single one of a determined direction and amount, so we can, by a reverse process, consider a single force as if it were

produced by the action of two or more. This is termed *resolving* a force, and is necessary for the proper comprehension of a great number of mechanical effects. The forces that are represented as resulting in another are called the *component* forces; the angle at which the two components are made to act may be any that is required. All that is necessary to represent them is to complete about this angle a parallelogram of which the given force shall be the diagonal. Thus to resolve the force F N (fig. 3) into two in the directions Fx and Fy; from N draw N S and N T parallel to Fx and Fy, then F T and F S will be the two components, because, by the parallelogram of forces, these two would give F N as a resultant.

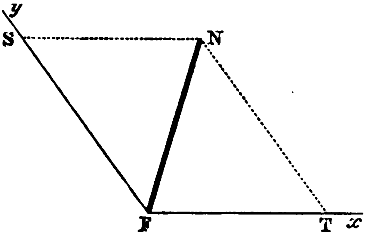

Fig. 3.

In practice, a force is most frequently resolved into two acting at a right angle, because this method presents greater facility in calculation. In this case, N T (fig. 4) becomes perpendicular to F x, so that $FT = FN \cos a$, and $FS = NT = FN \sin a$. If we only require the force exerted in a particular direction, without considering the other component, we have only to multiply the force by the cosine of the angle in which it is inclined to the required direction; the other component in most cases representing the loss of force incurred by the change of direction.

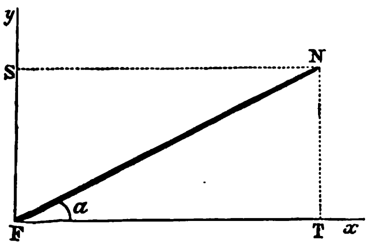

Fig. 4.

Thus, if a man standing on a high embankment draws a boat towards him, his efforts will not be as effective as if he was on a level with the boat, because he is necessarily pulling partially upwards; that is, let us suppose, in the direction F N (fig. 4), when, as we have seen, the result, in the direction he requires it, that is, towards x, will only equal F T. If a were an angle of 60°, a pull of 60 lbs. in the direction F N would give one only of 50 lbs. in the horizontal line F x, because cos. $60° = \frac{1}{2}$. On this account the tow-path of a canal should be as low as is consistent with safety, in order to make the rope nearly horizontal.

The consideration of work on a canal will afford another illustration of the resolution of a force. Let B A (fig. 5) be the tow-rope of a canal barge, supposed horizontal, then BD being the direction in which motion is to be given, let us suppose the strain on the rope to be 40 lbs., and the angle to be a 25°, then the cosine of a being ·9, nearly, the pull in the onward direction B D will be $40 \times ·9 = 36$ lbs., being a loss of the tenth part of the force applied. By giving greater length to the tow-rope we can diminish the angle a, and consequently increase its cosine, so that the loss of power will not be so great; and any one who visits a canal can see, by the length of the rope employed in traction, that, without probably understanding the reason of it, bargemen are fully aware of this fact.

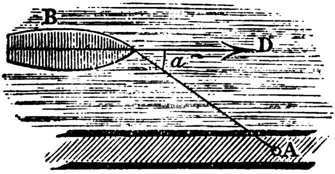

Fig. 5.

8. This subject of the resolution and composition of forces is one which admits of a vast variety of illustrations, and is one of great use in practical problems on mechanics; it will, therefore, be of great advantage to the young student to consider carefully the following cases, and endeavour graphically to delineate the results with any assumed amount of force and direction.—How does the wind support a kite in the air, and give it an upward motion from a horizontal force?—Given the

surface of canvas in a boat's sail, and the average pressure of the wind per square foot: find the force actually propelling a boat tacking at different angles to the wind?—Why does the recoil of a bow send the arrow forward?—What makes the arms of a windmill revolve? A careful examination of these and similar questions will form the best possible exercise for arriving at a clear comprehension of the mode of production of various mechanical effects.

9. CONDITIONS OF EQUILIBRIUM.—When any number of forces act upon a point without producing motion, they are said to be *in equilibrio.* In this case any one of them is equal and opposite to the resultant of the others. For instance, let three forces, represented by R P, N P, and S P (fig. 6), be directed against the point P; then for the two former we may substitute a single force, represented in amount and direction by T P; we shall then have two forces, T P and S P, acting upon a point, and unless these were equal and opposite, motion would ensue; but we have assumed that the point is at rest, therefore S P must be equal to the resultant of R P and N P, but act in a contrary direction.

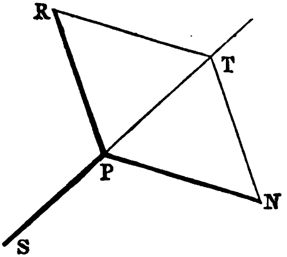

Fig. 6.

10. When a number of points are connected together by rigid lines, so that they cannot in any way alter their relative positions, they are called a system, and whatever force is applied to one will necessarily affect all. When all the points to which forces are applied, and the directions of the forces are in the same plane, some point in the plane is assumed, supposed immovable, but about which it is possible for the plane to revolve, and the product of each force by its perpendicular distance from this point is called the moment of the force; if, then, the sum of the moments, which tend to turn the system one way, is equal to that of those which tend to turn it

in the contrary direction, equilibrium will result. All the forces will in this case be found to have a single resultant in the direction of the assumed point.

11. It is obvious, from the very meaning of the term, that if any number of forces be applied to a system, they will be in equilibrio when they have a single resultant directed against a *fixed* point; because we can suppose all the forces to be removed, and the single resultant applied in their place; we shall then have a force endeavouring to move what is immovable; its efforts, therefore, can produce no effect.

Let us now examine how we can apply this fact in order to ascertain the conditions of equilibrium of a line acted upon by two forces in the same plane, and capable of revolution in that plane round a fixed point. Let F S and F T (fig. 7) represent the direction of the two forces, and R be the point round which the line S T is movable. Produce F T and F S until they meet at N, and conceive the forces to be applied at this point. We have then to inquire what should be their relative amounts in order that they should have a resultant in the direction N R. Join N R; assume N A to represent the amount of force at S; from A draw A C parallel to N T, and from the point of intersection C draw C B parallel to S N. Then, according to the parallelogram of forces, N B represents the amount of force in the direction F T, which, combining with N A would give the resultant N C in the direction of N R. Let us now ascertain what relation exists between N A and N B. From R and C let fall perpendiculars upon S N and N T; then, because the two triangles N C A

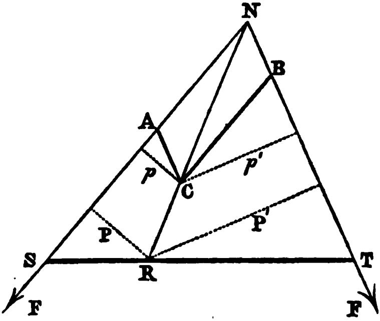

Fig. 7.

and N C B are equal, therefore $NA \times p = NB \times p'$; or $NA : NB :: p' : p$; now we know that $p : p'$ as $P : P'$, so that, substituting this ratio, we find

$$NA : NB :: P' : P;$$

that is, *the forces are in the inverse proportion to the perpendiculars let fall upon their lines of direction from the centre of motion.* We can express this in a somewhat different manner, by saying that the product of each force by this perpendicular distance is the same, which is equivalent to this—*the moments of the forces round the centre must be equal.*

LESSON II.

SIMPLE MACHINES.

1. We shall now proceed to the consideration of what are called the simple machines; viz. (1) the lever; (2) the wheel and axle; (3) the inclined plane; (4) the wedge; (5) the screw; and (6) the pulley.

The Lever.—A lever is an inflexible bar capable of turning on a fixed point, and acted upon at two other points by forces tending to turn it in opposite directions round the fixed centre of revolution. The bar may be of any size or shape, and the three points may be situated anywhere along its length. The fixed point on which the lever turns is called its *fulcrum*, and the two forces which act upon it are, for convenience of reference, distinguished as the *power* and the *resistance*.

2. If we suppose the bar to be reduced to a line, and to be without weight, we shall then have the theoretical or simple lever. Now, of course, there cannot be a rod strong enough to be inflexible, and yet without thickness and weight; but it is quite possible to imagine its existence, just as we are compelled, in geometry, to treat of lines without breadth; and, by considering the properties of this imaginary simple lever, we arrive at results capable of practical application to bars of any weight and thickness. Let us, therefore, first inquire what relation must exist between two forces applied to such a machine, in order that equilibrium may be preserved.

3. By referring to section 11 of the last lesson, it will

be seen that we have, to a great extent, already solved this problem. We there showed that so long as the two forces have a single resultant, passing through the fixed point, no motion can result, and that to secure this, the moments of the forces round that point must be equal. Hence, for the solution of all questions relating to the equilibrium of the simple lever, the following rule will be found sufficient when the power and resistance are in the same plane; *the power multiplied by the perpendicular from the fulcrum on its direction, is equal to the resistance multiplied by the perpendicular on its direction from the same point.*

4. This will be true, in every case, and of every kind of simple lever, straight or bent, when we are careful to recollect that it is the *perpendicular* distance, and not the length of the arm, that is to be used as the multiplier. The case, which most frequently occurs in practice, is that in which the lever is straight, and the two forces in a direction perpendicular to it; as, for instance, weights suspended from a horizontal beam; here the arms are the perpendicular distances, and the condition of equilibrium is represented thus:

$$P \times d = R \times d'. \qquad (a)$$

5. We will now apply this form to what are termed the three orders of levers determined by the relative positions of the resistance, the power, and the fulcrum. These are represented in the figure (8), and a mere inspection will be sufficient to show that in the *first order* the power and resistance are applied at opposite sides of the fulcrum; in the *second order* the fulcrum is at one end of the lever, and the power at the other; and in the *third order*, the power is intermediate between the fulcrum and the resistance. We will still suppose the bars to

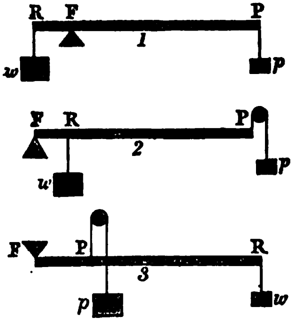

Fig. 8.

be without weight, each ten feet long, and divided in the proportion of 2 to 4, and the resistance, in each case, to be a weight of 100 lbs.; we shall then, by substituting their values for R, *d*, and *d'*, in formula *a*, arrive at the following results:—

In the First order $100 \text{ lbs.} \times 2 = P \times 4 \therefore P = \frac{100 \times 2}{4} = 50 \text{ lbs.}$

Second order $100 \text{ lbs.} \times 2 = P' \times 6 \therefore P' = \frac{100 \times 2}{6} = 33\frac{1}{3} \text{ lbs.}$

Third order $100 \text{ lbs.} \times 6 = P'' \times 3 \therefore P'' = \frac{100 \times 6}{2} = 300 \text{ lbs.}$

On comparing these results we find that, under the assumed conditions, the power required for equilibrium is less than the amount of the resistance in the first and second cases, when there is consequently said to be a mechanical advantage; but considerably greater than it is in the third, when a mechanical disadvantage results.

6. When the forces are not perpendicular to the lever, or when the lever is bent, the arms no longer coincide with the perpendicular distances, and we are compelled to use a slightly more complex formula. Thus, if, as in the figure (9), a weight suspended at R be kept in its position by a cord held in the direction P C, then F p and F p' will be the perpendicular distances; but F p = F P sin a, and F p' = F R sin a', so that our formula for equilibrium will be calling F P—l, and F R — l':

$$P \times l. \sin a = R \times l.' \sin a'.$$

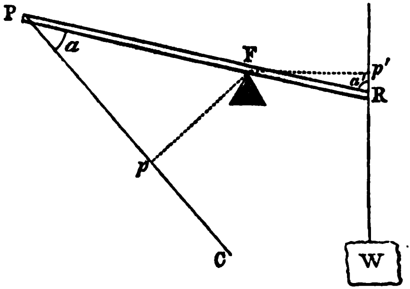

Fig. 9.

From this formula, and by reference to the figure, it will be seen that, when a lever is in action, the amount of power necessary to balance a given resistance will be constantly varying with the change of position. The mechanical advantage, however, afforded by a lever, may be taken as the difference between the power and the resistance, when both are applied perpendicularly, as this supplies a fair test of its efficacy. It must further be remembered, that whenever, in any machine, a small weight counterpoises a larger one, it can only do so, because some portion of the larger weight is thrown for support upon the fixed point of the machine. It was from a full appreciation of this great truth in mechanics that the celebrated Archimedes exclaimed, "Give me but a standing-place (*i.e.* some fixed point independent of the earth), and I will move the world itself."

7. Whenever the weight of a lever is so great as materially to influence its operations, it must be taken into account as a third force acting downwards at its centre of gravity, when the bar is of equal thickness throughout its length; or as two forces equal to the weight of each arm, and acting at the centre of gravity of each respectively when the dimensions are not equable. In either case, the sum of the moments acting at one side of the fulcrum must, to produce equilibrium, be equal to those acting at the other side.

8. Levers are used for a great variety of purposes, in natural and mechanical actions; sometimes to ascertain the equality of two weights; sometimes to increase the weight that a given power can raise; and sometimes to increase the velocity impressed by a force, or the distance through which the resistance is overcome. We shall consider some of these applications with reference to the three orders of levers already enumerated. The most important application of the lever, of the first order, in which the fulcrum lies between the power and the resistance, is to the purpose of weighing articles of every description.

9. COMMON BALANCE.—Of these weighing machines, the most frequently employed, from its simplicity and accuracy, is the lever of equal arms, represented in fig. 10, in which, provided the arms be symmetrical, the weight of the beam need not be taken into account, as its centre of gravity will necessarily be in the same vertical line with the point of support. The distances *a c* and *c b* being

equal, equilibrium will result when the weights applied at *a* and *b* are of the same amount, that is, since the two sides are supposed to be perfectly similar, when the weights placed in the two scale-pans, *s*, *s*′, are equal; if then a known weight be placed in *s*, that of any commodity, which, placed in *s*′, balances it, will be ascertained. Although we thus see that the construction of the common balance for ordinary commercial purposes is extremely simple, yet great accuracy is required in making one which shall have perfectly accurate results, particularly when delicate differences of weight have to be exhibited. The chief points to be attended to are, first, that the centre of gravity *g* of the whole machine, and the weights placed upon it, shall be below the point of suspension *p*, otherwise the balance will not, if disturbed, recover its horizontal position, but will either rest in any position indifferently if the two points coincide, or will fall to one side on the slightest deviation from the horizontal, if *g* be higher than *p*. Second, the *stability* or readiness in recovering its position, when disturbed, will depend upon the distance *p g*; the greater this is the more rapidly will the horizontal position be resumed. Third, the *sensibility* of the balance, that is, its capability of exhibiting slight differences of weight, will depend upon the length of the arms, and increase as the distance *p g* diminishes. From this it follows that the qualities of sensibility and stability cannot be combined, unless, as is sometimes done, by having an adjusting screw, by which the distance *p g* can be varied according to the purpose for which the balance is required. If the

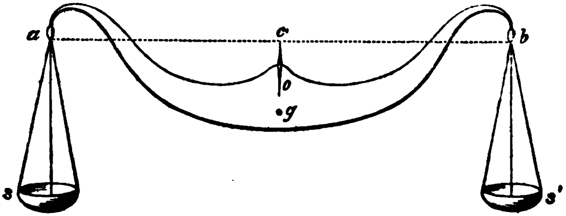

Fig. 10.

centre of gravity of the unloaded beam be in the line joining the points of suspension, $p\,g$ will be independent of the weights applied; but if it be above this line, the sensibility will diminish, and the stability increase, as the weights become greater; if, on the other hand, it be below this line, the contrary will be the result. If the joining line be above the axle, as in the figure, the scales will serve only for weights below a certain limit.

The greatest lightness of beam, consistent with sufficient strength, should be adopted for a true balance, and the axis ought to be as free as possible from friction.

10. A balance may be so constructed as to preserve the horizontal position when unloaded, although quite false in its indications when weights are attached. This is done by making the arms of unequal lengths, and increasing the thickness of the shorter one so as to secure equilibrium. When, in this case, the weight is placed at the end of the shorter arm, and the commodity to be weighed at the longer, the latter, acting at a greater distance from the fulcrum, must, to produce equilibrium, be less in amount, and consequently a fraud would be perpetrated on the purchaser, difficult at first to detect. A false balance of this kind is easily detected by putting known equal weights in the opposite scale-pans, when it will be found that the scales will not balance, and the true weight of the commodity may be ascertained, in spite of the untrue indications of the scales, by removing it and seeing what weights put in its place will balance the loaded scale-pan.

11. A *bent lever balance*, represented in fig. 11, in which the weight is denoted by an index, is readily used and speedy in its indications, on account of its great stability; it is therefore frequently employed for weighing corn, coals, and other commodities. The zero of the scale is marked on the circular arc, at the point where the index stands when the balance is unloaded, and from this arcs are measured off that shall denote an increase of 1, 2, 3, &c. in the weight. If the arm $c\,d$, and index $c\,i$, be at right angles, and the former horizontal when unloaded, these arcs will be those whose tangents increase in the same order, and which will con-

sequently themselves *decrease* in size, so that a quadrant would give an infinite range.

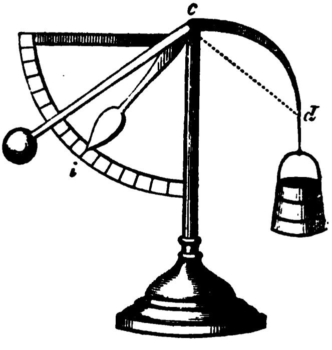

Fig. 11.

12. **Danish Balance.**—There are other descriptions of lever balances, in which the commodity is weighed by altering, not the amount of the counterpoise, but its position relatively to the fulcrum. This may be done in two ways—either by moving the counterpoise or altering the point of suspension. In the *Danish balance*, a very simple and portable instrument, the latter method is adopted. Thus fig. 12 is a rod with a hook at one end to support the commodity to be weighed, and a knob at the other for a counterpoise: the loop *l* can be shifted along the rod. The principle of its action can be easily understood: let *o* be the centre of gravity of the unloaded rod, from which consequently it will swing horizontally; if now we attach any weight at *d*, the common centre of gravity will move a certain distance from *o* towards *d*, and to preserve the horizontal position the loop must be moved the same distance. We have, therefore, only to graduate from *o* to *d* for equal movements of weight, and the instrument is complete. The divisions of th

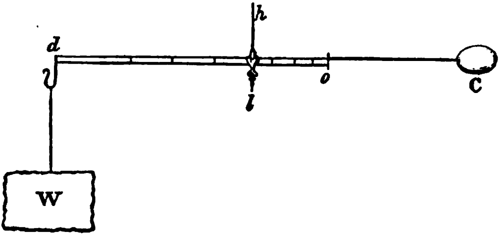

Fig. 12.

scale will diminish as we approach *d*, but these lengths are easily calculated.

13. Steel-yard.—In the steel-yard (fig. 13), the contrary method is employed: the fulcrum remains at rest, while a constant weight, resting on a knife-edge, is moved along the yard. The arrangement of this balance is very simple: if the length of the arm which carries the weight be two inches, and the movable counterpoise be one pound, then at two inches from the fulcrum it will indicate a weight of one pound, at four inches two pounds, at six inches three pounds, &c. This is on the supposition that the unloaded steel-yard poises horizontally when unloaded; a condition which, however, is not necessary; it may be made to rest in any position, but then the zero of the scale will not be at the fulcrum, but at a distance from it, depending upon the position of the centre of gravity of the machine. By using two equipoises of different weights the range of the balance may be increased, because the divisions will indicate equal multiples of whichever equipoise is used.

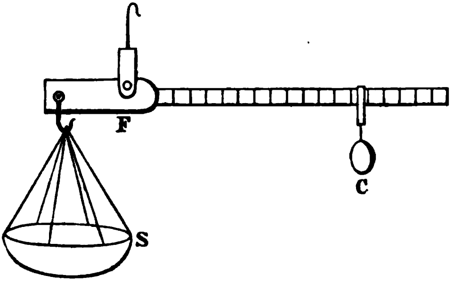

Fig. 13.

14. We might examine many other instances of the use of levers of the first order; but the principle is the same in all, and the reader's own observation will enable him, by the position of the fulcrum, to tell on inspection those which belong to this class. We shall merely enumerate the following, as familiar examples and practical exercises in discovering the relative positions in each case of the power, the resistance, and

the fulcrum;—the handle of a pump,—a poker when it rests against the bar of the grate,—a hammer in drawing a nail, are single levers of the first order,—and scissors, pincers, shears, &c., are combinations of two of these acting together.

15. Instead of considering the simple problem of the lever of the *second order*, let us consider the conditions as to pressure of a horizontal beam of wood or iron, resting at the extremities upon two supports, and sustaining a given weight from any point in its length, as represented in fig. 14. In this case we may consider the beam as a lever of the second order, having its fulcrum at one end, supposing s to be the fulcrum, then by the conditions of equilibrium, $W \times so = P \times ss'$, from which we can find P the pressure on the support B, and in a similar manner that upon A can be found. If the beam be of uniform thickness, its weight may be considered as acting at its centre, and will of course be equally divided between the two supports, otherwise we must ascertain the position of its centre of gravity, and estimate its effect, as we did that of the attached weight. Of course the same reasoning applies to the case of two men carrying a load slung from a pole.

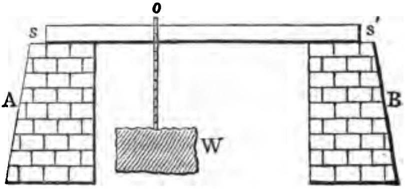

Fig. 14.

The oar of a boat is a lever of the second order, of which the fulcrum may be considered as in the centre of the blade, the resistance that of the boat acting at the rowlock, and the power applied by the hands of the rower. A wheelbarrow, so far as it acts in supporting the weight upon it, affords another illustration; a door, also, or the lid of a chest, is moved on the same principle, and nutcrackers are but double levers of this class.

16. In levers of the *third order* the power always acts under a mechanical disadvantage—that is, it will not sus-

tain a resistance equal in amount to itself. The use of such a machine is, however, frequently advantageous, because the resistance moves through a greater space than the power, and consequently with greater velocity; and thus in many operations, in which strength is not so much required as rapidity and ease of motion, it is of great assistance to the workman. We have already spoken of the treadle as an instance of this; but cannot give a more beautiful illustration than the mode of action in the human arm, in which the elbow is the fulcrum, and the muscular tension acts between it and the hand, in which the resistance is experienced. A pair of tongs is a double lever of this kind. As an index, whenever it is desirable to magnify the apparent effect of a small motion, it is also found extremely useful, and the same principle is applied in the arts for taking a magnified or reduced copy of a plan or drawing.

17. Any number of levers may be made to act in concert, and with multiplied effect, by making the power in the first become the resistance in the second, and so on, through as many as are required. By this means, in the weighing-machine for ascertaining the weight of loads of hay, straw, &c., the platform upon which the cart rests is supported by a system of levers, connected with the steel-yard upon which the counterpoise is placed, so that a small shifting-weight is sufficient to indicate the amount of the heaviest weight the platform can sustain. Such a system of levers is sometimes called a *compound lever*.

18. Bent levers can be often advantageously used to alter the direction of a motion of limited extent from the horizontal to the vertical, or the reverse. Let A F B (fig. 15) be a bent lever, having the fulcrum at the elbow, F, then if a short motion backwards and forwards be given to the end, A, the end B will be moved up and down. This mode of construction

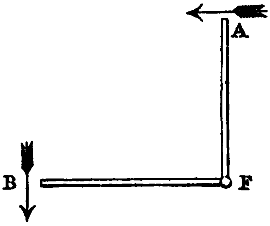

Fig. 15.

has been applied to give the required horizontal motion to the saw in sawing-machines.

LESSON III.

SIMPLE MACHINES—*continued.*

1. **The Wheel and Axle.**—Simple and efficacious as the lever is in its action, it labours under the practical disadvantage of being limited as to the distance through which it can be worked; when the acting end has been raised or depressed to its limit, no farther effect can be produced on the resistance without a change of position of the lever. In the wheel and axle, the principle of which is very similar to that of the lever, we get over this inconvenience, and are enabled to produce a sustained and continuous effect. This machine (fig. 16) consists of a cylinder or barrel, B, round which a rope sustaining the weight can be coiled, and a wheel, W, round the circumference of which the power acts. The wheel and axle are firmly attached to each other, and revolve upon a common axis turning on pivots, P and P′, at its extremities. As the power applied at the end of the rope E descends, it raises the weight by coiling the rope F to which it is suspended round the barrel, an action which will manifestly be continuous until the length of rope is exhausted. It is for this reason sometimes called the perpetual lever.

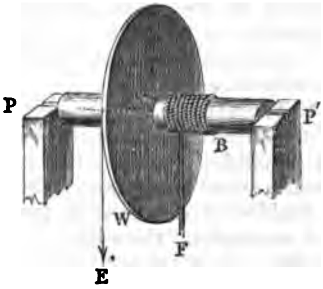

Fig. 16.

2. The mechanical principle of this machine can be readily understood by reference to the lever.

Let fig. 17 represent a vertical section of the wheel and axle, then we may consider A B as a lever of the first order whose fulcrum is at C, and consequently $P \times C B = W \times A C$, that is, the power and weight are to each other as the radius of the barrel is to the radius of the wheel. This proportion will enable us to solve any question that may be proposed on the relative dimensions and effects of this machine.

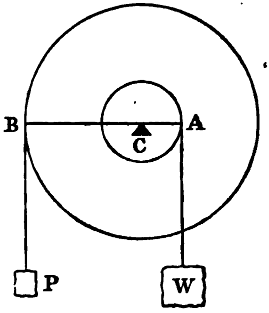

Fig. 17.

3. When, for the wheel and its rope, a cranked handle is substituted, then this machine becomes the common windlass figured in the First Book. When a number of bars are inserted into the wheel or the barrel itself, it becomes the capstan used on board ship; while if the wheel be made of some width, and animal power be applied on the inside, we see the manner in which the donkey is employed to raise water from the deep well in Carisbrook Castle, while dogs are employed in a similar manner at Valparaiso.

4. There are many contrivances for increasing the power of this machine without increasing the size of the wheel or diminishing that of the axle to an inconvenient or unsafe extent: the most common is the employment of a double barrel, one of larger diameter than the other, and suspending the weight from a rope which coils in opposite directions round the two barrels; the practical axle in this case is only the *difference* between the two.

5. The Inclined Plane.—This very simple machine is used principally for facilitating the raising or lowering of heavy bodies. It may be constructed of any material; a sloping bank of earth, a strong plank raised at one end, and the slips from which a ship is launched, are all inclined planes. Under this denomination may, in fact, be included any sloped surface along which weights are drawn.

Suppose a heavy body to be placed upon a plank fixed horizontally, it is plain that it will remain at rest, provided the perpendicular from its centre of gravity falls within the surface resting on the plank; if, now, we gradually raise one end of the plank, the body will, after some time, either topple over or slide down the slope thus made. If it be of such a form as not to fall over, the only force keeping it in its place will be the cohesion between its surface and that of the plane; and the height to which the plank can be elevated, without causing a sliding descent of the body, will depend upon the character of the two surfaces in contact, that of the body and that of the plane. It is by experiments conducted in this simple manner, that the amount of *friction* between different substances is determined, the angle at which one begins to slip upon another is called the limiting angle, or coefficient of friction. As this amount of friction is very variable, and must be taken into account *in addition* to the mechanical conditions of equilibrium, we shall limit our considerations at present to the case of a body moving without friction, and inquire, as we have done in the other simple machines, what relation must exist between the power and the weight, from which we can deduce the mechanical advantage gained by its use.

6. Let AB (fig. 18) be a section of a plane inclined to the horizon at an angle a, and D that of a body resting upon it and sustained by a cord parallel to the plane, and passing over a roller R; we have then to examine the relation between the weight of the body and that of the counterpoise P. As the plane is supposed to be rigid, any force directed perpendicularly against it will be counteracted by its resistance; if therefore we resolve the force representing the weight of the body into two others, one

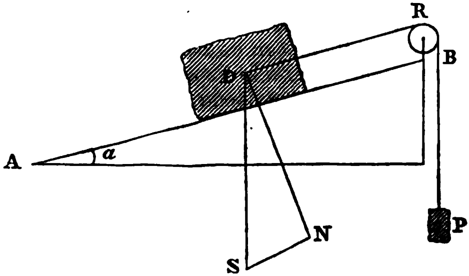

Fig. 18.

pendicular to the plane and the other parallel to it, the latter will represent the amount of force acting to give motion down the plane, or that which has to be sustained by the weight P. Draw D S in the direction in which gravity acts, that is, perpendicular to the horizon, and assume it to represent the weight, then its two components will be D N perpendicular to the inclined plane and N S. Thus the actual weight of the body is to its tendency downwards, or the weight to be supported, as the line D S is to S N; but as a little inspection will convince us that the triangle D S N is similar to A B C, it follows that D S : S N :: A B : B C, from which we conclude that the weight in this machine is to the power as *the length of the plane is to its height*. From this proportion, which is sufficient to solve most questions, we can deduce a form simpler still: since P : W :: B C : B A, P must be equal to $W \times \frac{B\,C}{B\,A} = W. \sin a$, so that to estimate the power we need only multiply the weight by the sine of the angle at which the plane is inclined to the horizon.

7. All hills upon turnpike roads, and gradients on railroads, are inclined planes, and the force exerted in surmounting them can be readily calculated. Thus suppose the traction on a horizontal portion of a railroad to amount to 10lbs. per ton; this we may consider constant for the same velocity, but when the locomotive arrives at a gradient of 1 foot in 224, it has an increased work of $\frac{1}{224}$th of a ton, or 10 lbs. to accomplish, making in all 20lbs. per ton: thus we see that even by so slight an elevation the work of the engine is doubled.

When a sloping plank is used for ascending a height, battens, or small pieces of timber, are nailed across to prevent the feet from slipping, and the stairs of our house are only a farther extension of this principle.

8. This machine may be used to raise a weight in a different manner by giving motion to the plane itself; it is then called the moveable inclined plane. In this case (fig. 19) the plane is pushed under the resistance R, by a force acting parallel to its base, in the direction P X. Resolving the resistance into a force perpendicular to the plane and one parallel to P X, the latter,

N S, will represent the power required for equilibrium; so that, reasoning as in the last instance, we may find that the power is to the resistance as *the height of the plane is to its bâse.* Many cutting tools, such as the chisel, plane, &c., are constructed on this principle, but its most important application is in the *screw,* which gives to it the same advantage of continuous action that the wheel and axle does to the lever.

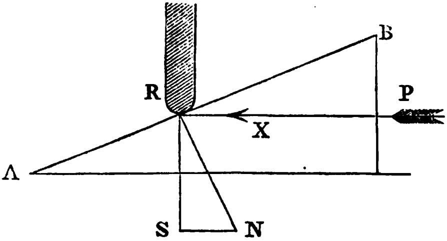

Fig. 19.

9. The Screw.—This consists of a small inclined plane wrapt round a cylinder, and may be familiarly exhibited by twisting a section of a plane cut in paper round a lead pencil. This is all that is necessary in screws for penetrating, such as those used by carpenters, and cork-screws; but when it is used for giving pressure or lifting weights, an additional contrivance is necessary. In this case the projecting plane, called the thread, of the screw is fitted into a corresponding groove cut in the inside of a nut, and the power is applied by means of a lever fitting into either the nut or the head of the screw.

The amount of force is easily calculated when we consider the distance between two threads as the height of an inclined plane, and the circumference of the cylinder as the length of it; we then find by the theory of the moveable inclined plane (see sec. 8), that the power is to the resistance *as the distance between two threads is to the circumference of the cylinder;* or when we use a lever, to the circumference of the circle described by its extremity. By means of a fine screw and a long lever, an enormous pressure or lifting power can be secured;

and until the invention of the hydrostatic press (to be afterwards described), this machine was the most powerful that could be employed for these purposes.

10. **The Wedge.**—Another form of the inclined plane is the wedge, employed for splitting or rending timber, or for giving a small lift to a great weight. It may be either of the form figured at p. 247, or double, with a common base in the centre. The latter form, which is that most frequently employed in rending, because its action is equable on both sides, is here represented. Although in its structure the wedge is exactly similar to the inclined plane, its mechanical action is different, as the force applied is generally percussion instead of pressure, and on this account it is not expedient at present to enter upon a calculation of the results produced through its agency.

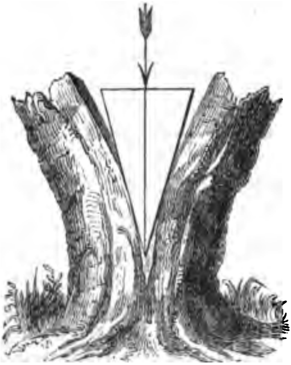

Fig. 20.

EDWARD PURCELL.

LIFE OF BENJAMIN FRANKLIN.

BY JAMES S. WHITE.

LESSON I.

1. **Franklin** tells us that his father, among the instructions given to him when a boy, frequently repeated this proverb of Solomon, "*Seest thou a man diligent in his calling, he shall stand before kings, he shall not stand before mean men.*" "I thence," continues Franklin, "considered industry as a means of obtaining wealth and distinction, which encouraged me,—though I did not think that I should ever literally *stand before kings*, which, however, has since happened; for I have stood before *five*, and even had the honour of sitting down with one, the king of Denmark, to dinner." Benjamin Frank-

lin, whose words have just been quoted, and who, by the most honourable means, and the practice of the highest virtues, rose from an obscure origin to great distinction in his native country and in the world at large, was born of humble parents at Boston, in New England, in the month of January 1706. He was the youngest son of seventeen children, and, showing an early readiness in learning to read, was destined by his father to the service of the church; and accordingly he was sent at eight years of age to a grammar-school, where he rose rapidly in his class. But in less than a year he was removed to an inferior school, as his father, being burdened with a numerous family, was unable to support the more expensive education which was necessary to fit his son for the church. Here he learned to write a good hand very soon, but failed entirely in arithmetic; and at ten years old he wa

taken away to help his father in his business, which was that of a tallow-chandler and soap-boiler. At this early age the school-education of Franklin was brought to a close: the admirable cultivation, which his mind subsequently underwent, was due to his own unassisted efforts in the midst of considerable difficulties.

2. Little Franklin, disliking his father's trade, wanted to go to sea, but his father refused his consent. It was now that he taught himself to swim, an accomplishment which was a great source of recreation to him, and which he highly recommends in his writings. He continued to be employed in his father's business till he was twelve years old; but his dislike to the trade not abating, another business had to be chosen for him. Young Franklin's early taste for reading had become a real passion. All the money that came into his hands was laid out in the purchase of books. He was particularly fond of voyages and travels. His father's little library, consisting chiefly of controversial books, was read with avidity. This bookish inclination at length determined his father to make him a printer; and, with some little hesitation on Franklin's part, who still had a hankering for the sea, he was bound apprentice to his brother James. In a short time he made a great progress in the business; and he now had access to more and better books. "Often," says he, "I sat up in my chamber reading the greatest part of the night, when the book was borrowed in the evening and to be returned in the morning, lest it should be found missing." Now it was that Franklin began to acquire the art of prose-writing, to his success in which he mainly attributed his advancement in life. He bought an odd volume of the Spectator; and he used to take some of the papers, and making short hints of the sentiments in each, lay them by a few days, and then, without looking at the book, he tried to complete the papers again. By comparing his Spectator with the original, he discovered some of his faults and corrected them. Now it was, too, that he resumed the study of arithmetic, which he had twice failed in learning when at school. All his former difficulties had vanished, and

he made himself master of the art with the greatest ease. Having met with a book, recommending a vegetable diet, young Franklin determined to adopt it, and proposed to board himself, if his brother would give him weekly half the money he paid for his board. He instantly agreed to it, and Franklin found that he could save half what was paid him. This was an additional fund for buying books; but he had another advantage in it, as he tells us:—"My brother and the rest going from the printing-house to their meals, I remained there alone, and despatching presently my light repast (which was often no more than a biscuit, or a slice of bread, a handful of raisins, or a tart from the pastrycook's, and a glass of water), had the rest of the time, till their return, for study; in which I made the greater progress from that greater clearness of head and quicker apprehension which generally attend temperance in eating and drinking."

3. While Franklin was an apprentice, his brother started a newspaper, which was called the "New England Courant;" and Franklin was excited to try his hand at writing some little pieces for the paper. But, being still a boy, and suspecting that his brother would object to printing anything of his in the paper, if he knew it to be Franklin's, he contrived to disguise his hand, and, writing an anonymous paper, put it at night under the door of the printing-house. It was found in the morning and communicated to some of his brother's friends, who themselves wrote pieces for the newspaper. What was young Franklin's delight to hear them, on reading his paper, commend it highly, and in their different guesses at the author, name none but men of some character for learning and ingenuity! Several other pieces, which were equally approved, were written by Franklin, and sent in the same way to the press; at last he discovered his secret. Some differences having arisen between his brother and himself, he left the former; and, not being able to get employment in any other printing-house of the town, he sold his books to raise a little money, privately went on board a sloop, and in three days found himself at New York,

near three hundred miles from home, at the age of seventeen, "without," as he says, "the least recommendation or knowledge of any person in the place, and with very little money in my pocket."

4. Meeting with no employment at New York, Franklin boldly pushed on to Philadelphia, which was one hundred miles further from home. Of the two printers who were then settled in the latter town, the first had been recently supplied with hands; but the other, whose name was Keimer, promised to employ him, and, a few days after, set him to work. Franklin being frugal and industrious now began to gain money. He passed his evenings very pleasantly with the young people of the town, who were lovers of reading, and lived very contented. At length Sir William Keith, the governor of the province, who introduced himself to Franklin, as having a high opinion of his abilities, and who professed to take a warm interest in his success, promised to set him up in business, and persuaded him to make a voyage to London, for the purpose of choosing the types, and establishing correspondences in the bookselling and stationery line. The governor further promised to send to him recommendatory letters, besides a letter of credit, to furnish him with the necessary money for purchasing the printing materials: and he led Franklin to believe that he had kept his promise; but, on arriving in London, Franklin found that the governor had played a pitiful trick upon him, and had never written or sent a single letter.

5. Thus Franklin was, for the second time, thrown upon the world, without credit or acquaintance, and with very little money. He lost no time, however, in seeking employment, and got into work first at Palmer's, and afterwards at Watts's, a large printing-house near Lincoln's-Inn Fields. He was called by his fellow-workmen in the latter establishment the "Water-American;" because he drank only water; the other workmen, near fifty in number, were great drinkers of beer. But Franklin soon let them see that strong beer was not necessary to make a man strong, by carrying up and down stairs a large form of types in

each hand, when the others carried but one in both hands; and a great many of them in consequence left off drinking beer, and adopted Franklin's mode of life. After passing about eighteen months at London, working hard at his business, and improving in knowledge, Franklin returned to Philadelphia, and was induced by Keimer, in whose service he was before sailing for Europe, to take the management of his printing-house, upon advantageous conditions. He soon, however, quitted Keimer's service, and entered into a partnership, to carry on printing with Meredith, one of his fellow-workmen at Keimer's. Franklin brought into the partnership industry and skill, and the other the money and stock.

6. The admirable means which Franklin adopted to procure a thriving business are best detailed in his own words. "In order," says he, "to secure my credit and character as a tradesman, I took care not only to be in *reality* industrious and frugal, but to avoid the appearances to the contrary. I dressed plain, and was seen at no places of idle diversion. I never went out a fishing or shooting; a book, indeed, sometimes debauched me from my work, but that was seldom, was private, and gave no scandal; and, to show that I was not above my business, I sometimes brought home the paper I purchased at the stores through the streets on a wheelbarrow. Thus being esteemed an industrious, thriving young man, and paying duly for what I bought, the merchants, who imported stationery, solicited my custom; others proposed supplying me with books, and I went on prosperously." It is no wonder that Franklin, acting in this judicious manner, soon found himself in the possession of wealth, and of a large circle of friends. He bought Meredith, who was ill-adapted for business, out of the partnership; and soon after married a wife with whom he lived happily till her death. He conducted a newspaper with great ability and profit, and employed that facility in prose writing, which he had so laboriously acquired, in treating the various political questions, which then interested the colony. Amongst the periodicals published by him was "Poor Richard's Almanac;" of which the distinguishing feature was, that all the available space

in its pages was filled with proverbial sentences, chiefly such as inculcated industry and frugality. These maxims were afterwards collected by him in one piece, called "The Way to Wealth," and obtained an extraordinary popularity.

7. We have traced thus at length the progress of Franklin's education, and the means by which he arrived at wealth and independence, because these details best display the natural force of his character; and because no part of his life furnishes a brighter and more useful example. We may not achieve the success of a Franklin, but we can imitate the virtues by which he deserved it.

8. Hardly had fortune begun to smile on Franklin's efforts, when he gave proofs of that public spirit and that activity in introducing practical reforms, which resulted in so much benefit to his country and in such glory to himself. About a year after he had dissolved partnership with Meredith, and when he was only twenty-four years old, he set on foot his first project of a public nature—that for a subscription library. This was the mother of all the North American subscription libraries, now so numerous. As his circumstances grew gradually more easy, and he became more and more emancipated from business, public affairs and public improvements received a larger share of his attention. He formed the first association for extinguishing fires; and at a later period, the first fire-insurance company. He established a philosophical society in Philadelphia. He raised subscriptions for the foundation of a public academy, which was the origin of the present University of Pennsylvania. He procured subscriptions and an auxiliary grant from the legislature to establish the first hospital in Philadelphia. In fact, there was not a project for the improvement of his fellow-townsmen, not a scheme for the advancement of the colony, of which Franklin was not the originator, or in which he did not take an active and principal part. A friend of his, who had met with little success in obtaining subscriptions to an hospital which he proposed to erect, came to Franklin and implored him to undertake the matter: "For," said he, "I am often asked

by those to whom I propose subscribing, 'Have you consulted Franklin on this business? And what does he think of it?' And when I tell them that I have not—supposing it rather out of your line—they do not subscribe, but say, they will consider it."

LESSON II.

LIFE OF FRANKLIN—*continued.*

1. WITH such activity in the management of his private concerns, and with such zeal in the service of the public, it was not long before Franklin found his way into public employments. In 1736, he was chosen clerk of the Assembly, a post of emolument; in 1737, he was appointed deputy postmaster of Pennsylvania; and in 1753 postmaster-general of America. In 1749, when he became disengaged from private business, he was put into the commission of the peace, chosen one of the common council, and soon after alderman; and the citizens at large elected him a burgess to represent them in the Assembly. He there distinguished himself by the introduction and support of measures, calculated to improve the condition, and strengthen the defence of the province. He neglected no opportunity of asserting and securing the political and constitutional rights of his fellow-citizens. He was always chosen one of the deputies, when the Assembly had occasion to intrust any important mission to some of their body. He was twice sent to London to arrange the disputes between the proprietaries and the Assembly, when he acted as the agent of the province of Pennsylvania.

2. It was during the second of these visits that the inauspicious attempt was made by England, to tax the American colonies without their consent, which led first to a most disastrous war, and finally to the separation of these magnificent provinces from the British Empire. Franklin was called to the Bar of the House of Commons, to inform the House of the state of affairs in America. The clearness, the precision, and the decided tone, with which he gave his evidence, produced a profound impression. On commerce, finance, administration, political interests—on all these questions he was found

equally ready; epigrammatic simplicity, which he employed when asserting disagreeable truths, gave irresistible force to his conclusions. The Stamp Act, which had occasioned the first outcry, was accordingly repealed, but unfortunately its principle was not abandoned: and new taxes were shortly afterwards imposed, which were only abolished by the defeat of England, and by the victory of America. During this great crisis, Franklin showed himself to be a zealous patriot, at the same time that he was a true friend of peace. He served the colonies by using his personal influence with many leading men, whose acquaintance he had made in England, and by giving his fellow-citizens most important advice and information on several occasions. He carried on a large correspondence with the principal English statesmen, and in every way laboured to avert the dreadful calamity which threatened both people. But the expostulations and the predictions of the philosopher were made in vain; and his activity in the service of the colonists drew upon him the enmity of those in power. He was removed from the office of postmaster-general of America, which had been honourably conferred upon him in 1753; and now, seeing that all his efforts to restore harmony between the two countries were unavailing, Franklin returned in the beginning of the year 1775 to America, where the war of Independence was already raging. The day after his arrival, he was chosen the delegate of Pennsylvania to the General Congress, and took a chief part in the firm and courageous proceedings of that assembly.

3. On the 2nd July 1776, the Congress published its celebrated declaration of Independence, to which Franklin contributed with all the weight of his character and of his talents. Towards the end of the same year, he was sent in the capacity of minister to France, when he succeeded in inducing the French Government to form an offensive and defensive alliance with the United States, Feb. 6, 1778. The personal celebrity of Franklin, as a French writer has well remarked, was the sole title which the Americans could find to supply the place of the honours and decorations with which the ambassadors

of Europe are invested. And whereas, in ordinary cases, the embassy dignifies the ambassador, it was he who dignified the embassy.

4. His reputation had preceded him to Paris: his scientific discoveries, which we are about to mention, had created a deep sensation there; and he was already known in person to several of the scientific and literary men in France, by whom he was received with the profoundest respect. In the midst of all his avocations, both public and private, Franklin, who loved to understand everything that came in his way, found time to devote a portion of his industry to scientific subjects. In his day, electricity excited the newest interest; at the same time that science was quite in its infancy. His attention was turned to it in 1746, by the arrival at Philadelphia of an electrical apparatus, which was presented by Mr. Collinson, F.R.S., to the library company, of which Franklin was a member. Franklin at once set about verifying old experiments and making new ones; and in 1747 he sent a series of letters to England, in which he noted the power of sharp points both to attract and to give out electric matter. In 1749 he conjectured the identity of lightning and electricity, and suggested the idea of protecting houses by pointed conductors, but did not prove it till 1752.

5. These letters attracted great attention in Europe, especially at Paris; and an experiment which he suggested in them, for drawing lightning from the clouds, was successfully performed by Messrs. D'Alibard and De Lor. This was the famous experiment of the electrical kite. A kite pointed with iron was raised during a thunderstorm: a key was tied to the hempen string of the kite, and the whole apparatus was insulated by adding a piece of silk to the end next the hand. The experiment succeeded beautifully. Sparks were taken from the key, and a Leyden jar was charged, and the phenomena exhibited were identically the same as if an electrical machine had been used instead of the kite. Soon after the experiment was tried at Paris, it was made by Franklin himself in America, and he records the exquisite delight with which he observed its success

Franklin immediately turned his brilliant discovery to account by planning a method of defending houses from lightning by pointed conductors, which have since been universally adopted. His conjectures and theories were at first slighted, and, it is said, even derided by the scientific men of London; but, in 1755, the Royal Society voted him the gold medal; he was chosen a member of the society, and the usual fees payable on admission were honourably remitted.

6. Franklin remained several years in France as Minister Plenipotentiary; and in 1785 he was recalled by his own wish, and returned to America. He was greeted on his arrival with the acclamations of the people, and the blessings of his fellow-citizens. The whole population of Philadelphia and its neighbourhood came out to welcome his return. He was chosen member of the supreme executive council for the city of Philadelphia, and shortly after was elected president of the same. He was delegate for Pennsylvania in 1787, in the convention appointed to revise and amend the Articles of Union; and his last political act was an address to his colleagues, entreating them to sacrifice their own private ends for the sake of unanimity. But though his philanthropy and zeal were undiminished, his life was now drawing to a close, and he expired April 17th, 1790, at the advanced age of eighty-four. The news of his death was received throughout the United States with deep and universal regret. His death was felt to be a national loss. The Congress and his fellow-citizens paid the highest honours to his memory; and in France, the National Assembly ordered a public mourning. He published in his lifetime several works of a moral, political, and scientific description, which were many of them translated into more than one foreign language.

7. Whether we regard the eminent position which he gained, or the means which he employed in his rise, few men deserve more of our admiration than does Benjamin Franklin, and still fewer can be held up so unreservedly for our imitation. His life is a rare instance of legitimate success achieved by legitimate means. Franklin did

not possess any brilliant qualities, nor was he, properly speaking, an ambitious man, and yet he enjoyed that consideration and renown which the brilliant and the ambitious often long for in vain. He was a bold inquirer, and a close reasoner; and his mind had a wonderfully practical turn. He was a first-rate man of business; and he carried the qualities, mental and moral, which chiefly contributed to his fortune as a printer, into the conduct of public business, and, as far as the nature of the case admitted, even into his scientific investigations. But, in the administration of public affairs, he was further actuated by a principle of philanthropy, which in him supplied the place of that personal ambition, which urges on men of a less noble cast of character. "I have always," he exclaims, "set a greater value on the character of a *doer of good* than on any other kind of reputation." To do good, one must have the ability to project; the skill, patience, and power to put in practice: and must, above all, be animated with the spirit of benevolence. In all these respects, Franklin was highly endowed and admirably educated; and, after a long and well-spent life, went down to the grave, having earned that reputation which he justly esteemed the most precious—that of benefactor of the human race.—JAMES S. WHITE.

THE WORTH OF FAME.

O! WHO shall lightly say that Fame
Is nothing but an empty name,
Whilst in that sound there is a charm
The nerves to brace, the heart to warm,
As, thinking of the mighty dead,
  The young from slothful couch will start,
And vow, with lifted hands outspread,
  Like them to act a noble part?

O! who shall lightly say that Fame
Is nothing but an empty name,
When, but for those,—our mighty dead—
  All ages past, a blank would be,
Sunk in oblivion's murky bed—
  A desert bare, a shipless sea?
They are the distant objects seen—
The lofty marks of what hath been.

O! who shall lightly say that Fame
Is nothing but an empty name,
When memory of the mighty dead
To earth-worn pilgrim's wistful eye,
The brightest rays of cheering shed,
That point to immortality.

A twinkling speck, but fixed and bright,
To guide us through the dreary night,
Each hero shines, and lures the soul
To gain the distant, happy goal.
For is there one who, musing o'er the grave
Where lies interred the good, the wise, the brave,
Can poorly think, beneath the mouldering heap,
That noble being shall for ever sleep?
No! saith the generous heart, and proudly swells,
"Though his cered corse lies here, with God his spirit dwells."

JOANNA BAILLIE.

Arts and Manufactures.

BY GEORGE DODD.

LESSON I.

TYPES AND TYPE-FOUNDING.

1. THE *types* used for printing are, perhaps, the most important of the materials employed in the art; since the very invention of printing, as it is called, in the fifteenth century, was really nothing more than a rearrangement or improvement in the management of the type. Printing was known much earlier; but not by means of separate or moveable types.

Three inventors—Gutenberg of Mentz, Faust or Fust, and Schöffer—aided in bringing forward this improvement. The first book ever produced with date, place, and printer's name indicated on the title-page, is believed to have been a psalter printed by Faust and Schöffer, at Mentz, in 1457. The first Bible was printed in 1460; and in a very few years the new art spread into most countries of Europe. William Caxton, whose name has become so celebrated, was not to any great extent an inventor; he was the first English printer, but he adopted methods previously employed in Germany. The first book printed in England was a Treatise on the Game of Chess, which Caxton put through the press in 1474. The first types were in what is called Gothic characters; but the Roman and Italic characters were not long afterwards introduced.

2. The art of making the metal types has undergone many improvements, from the days of Caxton to the present time; and it is now one of the most delicate varieties of working in metal. In ordinary English book-printing, there are about a dozen sizes of type employed, each size comprising both capitals and small letters; and each size has a technical name.

3. It need scarcely be said that, the larger the type, the smaller the number of words that can be introduced into one line. Type-founders estimate quantity by the number of lines contained in a column one foot in length. This number is 51 in respect to *great primer*, 205 in respect to *diamond*, and varies in the intermediate sizes according to the type. The present volume, for example, is printed in *long primer*, which has 96 lines to the foot.

4. When the type-founder has decided on the size of the type, he has to produce five varieties of every letter: these are full capitals, small capitals, small Roman, large Italic, and small Italic, which may be represented by the letter m, thus, M, ᴍ, m, *M*, *m*. Scarcely a page of an ordinary book is deficient of any of these five varieties. There must also be &c , ; : . ¶ — ([, and several other marks and characters, making the entire number about 200; and these constitute a *fount* of type. To produce this fount there must be 200 *punches*, 200 *matrices* produced from these punches, and 200 kinds of *type* cast from the matrices.

5. The first work to be done is to produce the 200 punches, one for each letter or character. A punch is a small oblong piece of steel, softened to facilitate working, and then hardened for use. The letter is formed at the end by hammering, engraving, and filing, and is the result of much patient and ingenious labour. Since the beauty of the type will depend primarily upon

that of the original punch, whether it be the dot of a small *i*, or a large capital M, there must be great care that the form and size are strictly attended to. The letter is produced in relief at the end of the punch, as in a type, but the right and left sides are reversed, so as to produce the proper effect when printed. From each punch a *matrix* is obtained. The matrix is a slip of copper, upon the face of which the punch is sharply but carefully struck, producing a cavity corresponding with, but reverse to, the letter.

6. From this matrix the type is cast. A small box or trough is made, in the bottom of which the matrix is temporarily adjusted. This box, called the *mould* (fig. 1), is peculiarly put together, that it may accommodate types of different thicknesses; for the *i*, the *n*, the *m*, &c., are all cast in the same mould, an appropriate matrix being used for each casting. The interior of the mould is of steel, and has a shelving orifice to facilitate the pouring in of the molten metal. The type-founder holds the mould in his left hand, retaining the matrix in its place by means of a spring. Near him is a small furnace, having at the top a pan or crucible containing melted type-metal. This metal usually consists of four parts of lead to one of antimony, but it varies slightly in different type-foundries. The metal, when hot, has a degree of fluidity which will enable it to enter all the fine lines of the matrix; while, when cold, it has sufficient hardness and

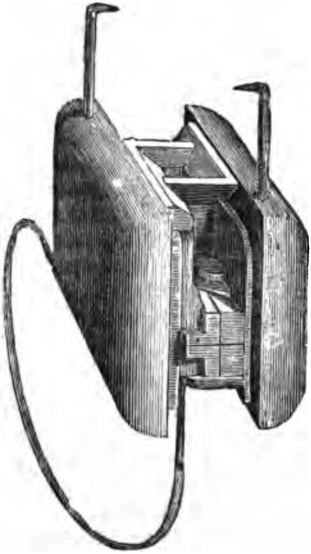

Fig. 1.

toughness to bear half a million inkings and printings before being worn out. The founder takes up a little of the melted metal in a small ladle or spoon; he pours it into the mould; he gives his left arm a peculiar upward jerk, to force the metal into the corners and indentations of the mould; he releases the spring which had kept the mould and matrix together, and extracts the hot but solidified type by a slight movement; he then closes the mould again, preparatory to another casting.

7. Now, notwithstanding the number, variety, and peculiar character of these movements, he performs them all in *one-eighth part of a minute!* Few examples are furnished in any branch of manufacture of such rapid manipulation: it shows what can be effected by long practice. It may be that the letter *m* is in his mould, and he continues to cast as many *m's* as are required for that fount or casting; after which he may proceed to letter *n*, *o*, &c., at the rate of about 500 per hour. Some type-founders can cast 700 or 800 in an hour, equivalent to about 12 in a minute. The types, when cast, are about an inch long, with the letter on one end; but they are rough and imperfect at the sides and bottom. They are taken one by one by boys, who break off the surplus metal at the end so rapidly as to effect 3000 or 4000 in an hour. The sides of every type are next rubbed upon a kind of gritstone, to remove protuberances and roughnesses; and even this work is done at the rate of 2000 per hour. A workman called the *dresser* then arranges the types in a compact mass, planes the lower ends to make them all exactly of the same height, carefully examines the face of each type with a magnifying-glass, and rejects those which are in any way defective.

8. In respect to the different letters of the alphabet, the type-founding or casting is conducted in the same way for all: but the *number* of casts from the same matrix depends upon the frequency with which a particular letter occurs. Printers, by long experience, have ascertained that in ordinary well-written English, the letters occur in about the following proportions:—

a	8,500	h	6,400	o	8,000	u	3, 400
b	1,600	i	8,000	p	1,700	v	1,200
c	3,000	j	400	q	500	w	2,000
d	4,400	k	800	r	6,200	x	400
e	12,000	l	4,000	s	800	y	2,000
f	2,500	m	3,000	t	9,000	z	200
g	1,700	n	8,000				

9. Many attempts have been made to cast type in larger numbers at once, placing many matrices in one mould; but most of such attempts have hitherto failed, although some of them are gradually coming into use. A method has been invented, also, of facing the types with a layer of copper or of silver by the electrotyping process. Other inventions, again, have been brought forward for making type by stamping, instead of casting. The process here detailed still remains, however, the most generally adopted in England.

LESSON II.

TYPE COMPOSING.

1. The types being formed, we have next to follow them into the printing-office, and to witness their use in effecting the printing of a book. As type-founding is a trade separate from paper-making; so is printing separate from both. Two or three only of the great printing-offices contain the requisite facilities for making type: most printers purchase their type ready made, from manufacturers who apply themselves especially to this art. The printer, however, has sufficient diversity in his operations; for he not only takes inked impressions from the types by means of the printing-press, but he arranges or *composes* the type to represent the literary production which is to be printed.

2. The compositor's work in a printing-office is remarkable in respect to the concert of mind and fingers which it requires. The compositor has the author's manuscript before him: he has to decipher writing which is sometimes almost illegible; and if he entertain a doubt as to the meaning of a particular

word or passage, he must exercise his judgment in selecting that meaning which best accords with the general sense of the paragraph. And while his mind and his eye are thus occupied, his fingers go through a rapid series of movements, taking up the separate types, and arranging them in proper order.

3. The compositor's *cases* are to him very important pieces of apparatus. They are shallow trays, in which the types are arranged for his use; and, as each kind of type must be kept distinct from all the others, that the compositor may not take up the wrong letter, they are placed in separate cells or divisions. As some letters are used more frequently than others, it is necessary to have a supply similarly varying in ratio; and, in order to save time, those letters which are most required should be placed nearest to the compositor's hand.

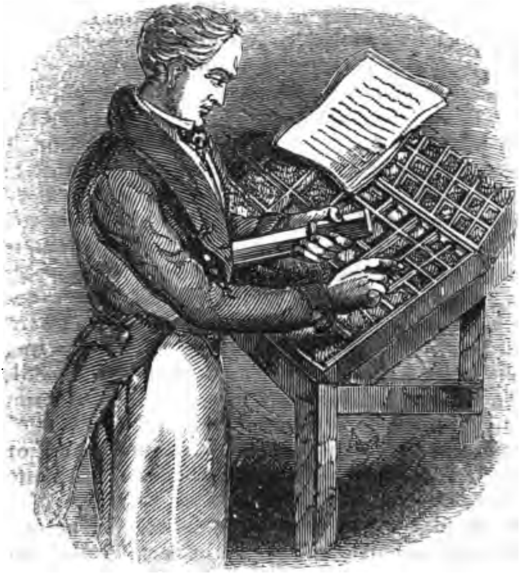

Fig. 2.

These requirements lead to a very singular arrangement of the compositor's cases, significant to him, but apparently confused as viewed by a spectator. The two cases are named *upper case* and *lower case*, in allusion to the position which they occupy on the compositor's table or desk; the lower case is placed nearly horizontal, while the upper case, farther from the hand of the compositor, is more inclined. Each case is divided into two halves, right and left. The left-hand upper case has 49 cells or divisions, containing the full or large capitals, the numerals, the dotted letters (such as ä, ë, ï), and a few other characters. The right-hand upper case has also 49 cells of equal sizes, containing the small capitals, the accented vowels (á, à, â, é, è, ê, &c.); and such marks as *, †, ‡, §, ‖, &c. The left-hand lower case has 24 cells, very unequal in size; the largest contains e; the next in size contain c, d, m, n, h, u, t, and what are called thick spaces; the next smaller contain b, l, and v; while the smallest contain j, z, x, &, æ, œ, and a few other characters. The right-hand lower case has 29 cells, of three different sizes: the largest contain i, s, o, a, and r; the letters f, g, y, p, and w, find receptacles in the next smaller cells; while the smallest are occupied by miscellaneous characters. All the letters appear strangely disordered; but the principle of arrangement is this—that when the left hand of the compositor is over, or in front of, the centre of the cases, the letters most wanted shall be nearest to his right hand.

4. Besides the letters, stops, numerals, notes, &c., there are various blank pieces of metal called *spaces*, *quadrats*, and *leads*, used for grouping the letters into words, the words into lines, and the lines into columns. The spaces are small pieces of metal placed between the words, to separate them sufficiently one from another; the quadrats are larger pieces for filling up blank lines; while the leads are slips of metal as long as the width of a column, placed between the lines to keep them wider apart. Specimens of printing without leads (such as the present volume) are called *solid*, and comprise by far the larger number; while the re-

maining examples are called *leaded.* Besides the pair of cases here described, the compositor is provided with another pair, the cells of which contain *Italic* type and characters.

5. The types being thus arranged in the cases, the compositor proceeds as follows:—He holds in his left hand a small apparatus called a *composing-stick* (fig. 3). This is a frame made of iron or brass, provided with a sliding end-piece, secured by a screw, which affords the means of adjusting it to the required width; and it is deep enough to contain about a dozen lines of medium-sized type. The compositor holding this in his left hand, reads as much of the manuscript as he can retain in his mind at one time, and picks up the successive types to form the sentence or phrase. He places the types, one by one, in his composing-stick, spacing the words so as to produce a uniformity of appearance when printed. Every type, as picked up, is placed, face uppermost, in the composing-stick, and retained there by a slight pressure of the left thumb. A small nick or notch near the lower end of the type guides the compositor in placing it in its right position. Numerous as are the movements of eye and fingers here combined, a compositor of average ability can pick up about 2000 types in an hour, and arrange them, with their proper spaces, and leads, and quadrats. When the compositor has filled the composing-stick with as many lines of type as it will conveniently hold, he takes them all out in one solid mass: he has acquired, by practice, the art of doing this without allowing any of the separate types to fall out. He places these lines of type on a long frame called a *galley;* and then proceeds with other similar portions until the galley in early filled.

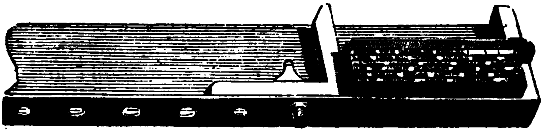

Fig. 3.

6. There then ensue the two operations of making up the lines of type into columns or pages, and correcting any errors which may have arisen. The several portions are placed one under another, until there are sufficient to form a page or column; and then the types for some sort of running head or title are placed at the top; while quadrats are placed at the bottom, to assist in binding all the lines closely together. All the spaces, leads, and quadrats, are below the general level of the type, to escape the inking-rollers. The page of type is bound round with cord; and then other pages are collected in a similar way. When there have been thus prepared 4, 8, 16, 24, 32, &c., of such pages, there is matter sufficient for one sheet of *folio*, 4*to*, 8*vo*, 12*mo*, 16*mo*, &c.; these technical names referring, not to the number of *pages*, but to the number of *leaves*. Taking a sheet in 16mo as an example (such as the sheets in the present volume), sixteen pages are arranged together in one group, and sixteen in another; each group comprising those which will be printed on one side of each sheet of paper. The pages of type are wedged into an iron frame called a *chase;* the united mass, called a *form*, can be lifted and carried about without disturbing any of the type; and two such forms are required for printing the two sides of every sheet of paper.

7. For convenience of description, the making-up of a form of type is here treated as if it followed immediately on the composing; but between the two processes the corrections and revisions are made. No reader of an ordinary volume, uninitiated in the operations of a printing-office, can imagine how numerous and tiresome are these corrections. In the first place, the cells of the cases may contain a few types wrongly arranged; and the compositor, placing his fingers rightly into the cell for letter *a*, may take out letter *o*. In the second place, the compositor may not be very clever at his business; he may occasionally dip his fingers into the wrong cells; or he may place letters upside-down; or misinterpret the author's meaning, and use a wrong word, or make mistakes in orthography and punctuation.

From some or all of these reasons, the first printed impression of a page or column of type always contains errors. The errors are detected in the following way: a *reading-boy* reads aloud the author's manuscript; while a *reader* examines closely every word and letter of the type on the printed sheet, and writes down on the margin a correction for every one of these errors. When the compositor has this corrected proof placed before him, his work is formidable; he has to pick out all the types which are in error, and insert the corrections; disturbing, perhaps, every line throughout a page, and every page throughout a sheet. He employs a kind of bodkin to draw out the types erroneously used; these he must return to their proper cells, and take out such others as he may need. All this seems to a looker-on to be attended with additional difficulty, inasmuch as the compositor must read all his type *backward*, or right to left; since every letter must be reversed on the type in order that it may appear in its proper position on paper.

8. But even this amount of correction is not sufficient. Either there are errors which the reader did not before see, or the compositor may have made new errors in correcting the former. The author, moreover, may wish to introduce improvements. When all these minute and important arrangements are completed, the *forms* are either sent to press at once, or they are *stereotyped*, and the printing is effected from the stereotype plates.

9. Before quitting the department of the compositor, it may be desirable to notice the completion of his labours. After the printing or the stereotyping (whichever it may be) is finished, the type is no longer wanted in its collected form; it may be taken to pieces, in order to be rearranged for printing some other work. This taking to pieces is called *distributing*, and is a part of the compositor's labours. He washes the ink from the types by the aid of an alkaline liquor; he loosens them from the chase; he takes them up a few at a time, and distributes the separate types into their respective cells with almost inconceivable rapidity. A clever com-

positor can distribute 50,000 in a day. If he make mistakes, he will have to bear the penalty; for in composing the next work, he will feel the consequence of any malarrangement of the types in the cells of his cases. If he let fall a mass of arranged type, whether in composing, adjusting, arranging, or distributing, the disordered heap—called, somewhat sarcastically, the printer's *pi*—is a source of much vexation and loss of time.

LESSON III.

STEREOTYPING AND PRINTING.

1. It has been just stated that, after the compositor has finished his labours, by setting up the type for printing, an intermediate operation is sometimes carried on, called *stereotype* or *stereotyping*. This word means *solid* or *fixed* type, in contradistinction to moveable. It is a mode of producing one solid plate of type for each page, instead of many thousand types, perhaps, all separate and all requiring careful adjustment one to another.

2. The important process of stereotyping is intended, not to increase the beauty or correctness of the printing, but to save time and expense. The printer is willing to bestow a little extra time and material before the printing begins, in order that he may economize still more largely afterwards. Where the amount of sale of a book can be nearly calculated beforehand, the stereotyping process is not required: it would cause more loss than gain. Such is the case in respect to newspapers, the daily or weekly sale of which is known beforehand within a few copies, and for which there is very little subsequent demand. So also, in respect to books which are not expected to have a large sale; the publisher prints off as many copies as he expects to sell, and then distributes the type for use in other works; if he require a second edition, he causes the whole type to be recomposed. When, however, a work is expected to sell largely and continuously, the publisher cannot venture to guess exactly how many copies he will require; if he print too many, he will suffer a heavy loss in paper and press-work; if he print too few, he may have to

bear the expense of recomposing the type within a few days after the printing; if he keep the type standing, made up into forms, he has a large amount of capital lying dead. He wishes to be relieved from this uncertainty, or rather from the penalty of it; and the stereotype process affords him admirable aid in effecting this. He can now print just as many copies as may be required for current supply; and may print again at any subsequent period without recomposing the type.

3. A stereotyped plate, we have said, is a solid mass or plate of type, which cannot be separated into its component letters. It is produced by a process of casting from the original type. When a page of type is set up, corrected, adjusted, and fully prepared, instead of being sent to the press-room, it is sent to the foundry, where all the arrangements for casting are provided. The original specimens of stereotyping produced early in the last century were obtained by cementing the actual types themselves together, so as to form a solid mass; but in the modern method the types are released uninjured, after having served as models for the stereotype plates. The stereotype-metal, very similar to type metal, is melted in large caldrons. The pages of type, if large, are cast separately; but if small, two or four are bound together into one form or frame. The face of the type is dusted with a small brush, slightly touched with oil or with black-lead.

Plaster-of-Paris, mixed with water to the consistence of cream, is poured over the type, and gently worked into the crevices with a brush; which, when set, is easily removed from the type-face, of which it presents a perfect mould or counterpart. From this plaster-mould the stereotype-plate is obtained, after being dried in a heated oven. The mould is enclosed in a kind of iron box of peculiar shape; this box is plunged into the caldron containing the molten metal; the metal enters at orifices in the corners, and spreads itself over the whole surface of the mould; the thickness of the layer so produced being regulated by the internal formation of the box. When the box is taken out of the caldron, it is gradually cooled, and the contents liberated; the plaster-mould is destroyed in detaching it from the stereotyped plate; and the latter is trimmed, planed, turned, and made quite ready for working.

4. A recent novelty is the application of gutta-percha to stereotyping processes. A page of type, or of mingled type and woodcuts, being adjusted, a layer of gutta-percha is pressed upon it; a gutta percha cylinder is impressed from this gutta-percha mould; and the printing is effected from the cylinder. Another kind of stereotyping is conducted as follows:—The type surface is prepared; a cake of warm, soft gutta percha is pressed down upon it, and kept in contact for a quarter of an hour; the gutta-percha mould so made is brushed over with black-lead, and an electro-copper cast is taken from it; and the printing is effected from this cast. In another method, the cast itself is gutta-percha as well as the mould, instead of being formed of copper by electrotyping. By a recent French invention, the cast or stereotype surface is made of a peculiar bituminous substance. In an older French method, a matrix or mould is obtained in a block of soft lead, by great pressure, from the type; and from this block stereotype plates are produced by a sudden falling of the face of the block upon a peculiar mixed metal, in a state of semi-fusion. All these processes are ingenious and interesting; but the old method of stereotyping through the medium of a plaster-mould is still found to be practically superior.

5. THE PRESS-ROOM, in which the presses and machines are worked, is necessarily much dirtier and more noisy than the compositor's department. We enter a room or shop in which levers, wheels, winches, spindles, shafts, rollers, cylinders, and other portions of machinery, are in motion all day long; and the noise thus produced is accompanied by the touch and the odour of ink and oil. In a first-class establishment, such as that of Messrs. Clowes (where two dozen printing-machines are worked by steam-power, in addition to an equal number worked by hand), the whirl and excitement are somewhat bewildering to a stranger on his first visit; but a little steady attention suffices to render intelligible

the admirable system and order on which the apparatus is worked. The first kind of press invented purposely for printing was that designed by Blaew, a printer at Amsterdam, in the sixteenth century. The sheet of paper was placed upon a stretched parchment called a *tympan*, and kept down by a light frame called a *frisket;* the paper was brought over the inked type, with a soft bed of blanketing to lessen the shock of the pressure ; a handle served to bring the form of types and the paper under the *platen* or upper board of the press, and another handle worked the screw of the press.

6. For more than a century, Blaew's press was the common form adopted in nearly all the printing-offices in Europe. It underwent various minor improvements at different times; but those introduced by Earl Stanhope, early in the present century, were so important as to

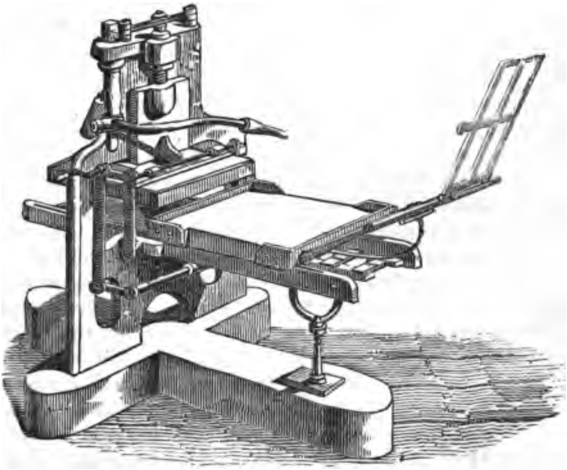

Fig. 4.

constitute the *Stanhope press* almost a new machine. In this press the form of types travels to and fro with much facility. The sheet of paper is adjusted by means of tympans and a frisket; it is brought down upon the form of types; the carriage which supports the form i moved onward until it comes under the press; and a lever brings the force of the press to bear upon the paper. It is the mode of effecting this pressure, which constitutes the chief superiority of the Stanhope press over the Blaew press. Many inventors, since the time of Earl Stanhope, have introduced modifications in different parts of the printing-press.

7. The paper in a large printing-office is stored, sometimes to the extent of thousands of reams, in a paper-warehouse, whence it is removed as wanted to the *wetting-room.* This room contains tanks or cisterns, through which clean cold water flows. A man or boy opens a ream of paper, takes a quire in his hands, dips it in the water, and places it on a board; he then takes another quire, and treats it in the same way; and thus proceeds until he has collected a large heap. The paper must be damp when printed on; and according to its thickness and quality, so are regulated the number of dips, the length of time during which the wetted sheets remain in a heap, and the employment or not of pressure. A heap of the damp sheets is taken to the press when the printing is about to commence.

8. The ink employed for printing differs considerably from writing-ink. It consists chiefly of lamp-black, prepared linseed-oil, and turpentine. That it should present a black colour, that it should dry quickly, and that its colour should be durable, are three requisites of good printing-ink. It is sold by weight, at prices varying from 1*s.* to 10*s.* per pound, according to the degree of excellence. The mode of applying the ink is by means of rollers. *An inking-roller,* fig. 5, is a wooden cylinder thickly covered with a peculiar elastic composition formed of glue and treacle, and provided with a convenient handle. The ink is spread upon an inking-table; the roller is rolled upon it, to take up a

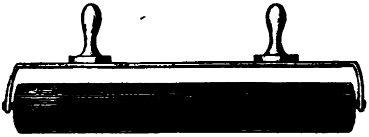

Fig. 5.

layer of the ink; and it is then rolled upon the form of type, to which it imparts the ink.

9. Paper, ink, and press being thus ready, the pressmen proceed busily with their labour. Two men can manage a modern printing-press. One inks the form, the other adjusts a sheet of paper on the tympan, folds down the frisket upon the paper, passes the form under the platen of the press, pulls down the handle or lever to obtain the necessary impression, draws out the form, opens the frisket, and takes the sheet of paper off the tympan, now printed on one side. Thus they proceed, sheet after sheet, until the requisite number of copies are printed. Supposing the number to be 1000, they first print that number of sheets on one side only, and return the form to the compositor, for him to distribute the type; they then take the prepared form for the other side of the sheet, and proceed in a similar way to print the blank surfaces of the 1000 sheets. The rate of working is about 250 sheets per hour, printed on one side. As the sheets are printed, they are removed from the press-room to the drying-room, where they are hung up until both paper and ink are sufficiently dry to enable the sheets to be collected in heaps. In newspaper-work many of the nicer processes are omitted for want of time. Although the average rate of working may be 250 impressions in an hour, it is much less than this in fine work, especially where delicate woodcuts are introduced; under such circumstances the rate of printing is occasionally so slow as 50 per hour. In the technical language of the printing-office, 250 copies are called a *token*, which regulates the wages of the pressman; the quantity is estimated at so many tokens, fractions not being noticed. Among other odd terms used by printers are *monks* and *friars;* a monk being a spot in a printed sheet in which the ink is too strong or black, while a friar is a spot too weak or light. It is expected from a good pressman that he should avoid both monks and friars.

10. We have now to attend to the important substitution of steam-power for manual labour. In the four-cylinder machine, now largely employed in print-

ing-offices, there are four tables or boards, at which are placed boys, called *layers-on ;* each table has a heap of damped but unprinted sheets of paper; and it is the duty of the boys to lay these sheets, one by one,

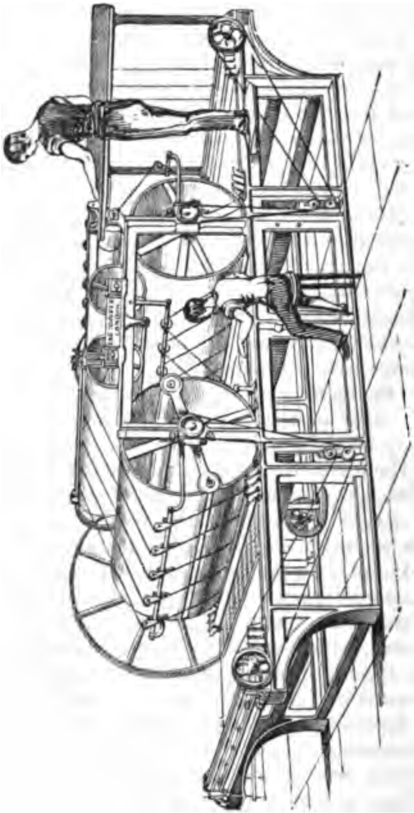

Fig. 6.

on a kind of travelling belt or apron. Each sheet is carried over a revolving cylinder, then over several rollers, and then under a second cylinder, by which ı pressed against the inked-type; the sheets, confined at the edges between tapes, travel onward after being thus printed, and arrive at certain parts of the machine where other boys, called *takers-off*, receive them. The type, arranged in 'form,' and presenting a surface equal to that of one side of the sheet, has a traversing motion to and fro; it passes under a series of inking-rollers which ink all the types in a beautifully-equable manner; and it then passes successively under the cylinders around which the paper is wound. Newspapers are generally printed at two different times, one side in one machine, and the other side afterwards at another machine; this often enables the editors to introduce more recent news, in the interval between the two printings. In book-printing, however, both sides are printed before the sheet leaves the machine; and it is thus managed:—The two forms or sets of type, one for each side of the sheet, are placed on a horizontal carriage a certain distance apart; and each form has a distinct set of inking-rollers, and a distinct printing-cylinder. The ink is contained in a kind of trough, into which a metal roller, called the *ductor*, dips; the ductor becomes coated with ink; a *vibrating-roller* touches the ductor, takes off a little ink, and deposits it on the inking-table; three or four *distributing-rollers* spread the ink equally over the table; and the table, then travelling onwards, imparts a thin stratum of ink to three or four *inking-rollers*, under which it passes. The two impression-cylinders then revolve; the two forms of type travel to and fro; and the various inking-rollers receive their supply. The sheet of paper, wrapping tightly around one cylinder, is rolled over one form of type, and receives one impression: it then winds upon the other cylinder, rolls over the other form of type, and receives a second impression; and it thus travels on, printed on both sides, to a spot where the *taker-off* receives it. The machines may vary in complexity: they may print one side only, or both; they may print one, two, or four copies at once; but the essential parts of the mechanism are alike in all. The inking-apparatus supplies and regulates itself; the form obtains its quota of ink just at the proper time; and the cylinder brings the paper in contact with the inked type exactly at the proper instant and in the proper spot. The whole of the operations are automatic, or self-acting, except the feeding of the machine with blank sheets of paper.

11. In the later and still more powerful *vertical* machine, such as is employed in printing the "Times" and the "Illustrated News," the nature of the operation differs in many remarkable particulars. The heart or centre of the apparatus is a vertical cylinder or drum, more than five feet in diameter. This drum is to receive, not the paper, but the type and the inking-tables. Every column of type occupies a flat, narrow, upright space on the surface of the drum; and as many of these spaces are placed side by side (like the successive sides of a polygon) as there are to be columns of type. Every page of type, thus arranged, is printed from eight times during one revolution of the drum; for all the four pages, forming one surface of a sheet of the "Times," occupy together only one-eighth of the circumference of the drum:—there is required, therefore, an eight-fold arrangement of inking-apparatus. There is a vertical reservoir of ink, from which a revolving *ductor* receives a continuous supply; there is an inking-table fixed to the drum, which, once in every revolution, receives a supply from the ductor; there are eight inking-rollers, placed equidistant around, but detached from the drum, and receiving in turn a supply of ink from the inking-table; and there are eight impression-cylinders, each bringing its own sheet of paper to be printed. Nothing can be more beautifully exact than the order in which these several parts come into action: their movements are timed with rigorous accuracy. During one revolution of the large drum, its inking-table passes under eight inking-rollers, which impart eight inkings to the type; and a process of printing takes place between every two of these inkings. The movements of the sheets of paper are wholly distinct from all this, and are very remarkable. There are eight feeding-boards, each containing a pile of paper, and each attended by a boy, the *layer-on*. Each boy pushes a sheet of paper off the heap: it is caught between two rollers, carried

downwards, and then sideways towards the drum; it is there seized by a cylinder, which presses it against the inked type, liberating it again immediately after the printing. Eight distinct sets of feeding-apparatus of this kind supply eight sheets of paper during each revolution of the drum; so that by the time this revolution is completed, there will have been eight copies of the "Times" printed on one side. The impression cylinders are about a foot in diameter, and are covered with cloth, to form a soft bed for the paper. It is evident that there are eight repetitions of the same process, all occurring during one revolution of the drum; eight layers-on, eight feeding-tables, eight sets of apparatus to convey the paper to the drum, eight impression-cylinders, eight sets of inking-rollers, and eight takers-off to receive the printed sheets. The drum revolves twice in five seconds, and there are therefore printed sixteen sheets in five seconds.

12. Such is the general arrangement of this wonderful machine. Without any essential alteration to the central drum, there might be a greater or lesser working-power, by increasing or diminishing the repetition of the other parts of the apparatus. The "Illustrated News" machine has four impression-cylinders, and four sets of apparatus for supplying ink and paper: consequently it produces only half as much work as the "Times" machine. If, on the other hand, there were a duplication of the type-forms on the drum, the "Times" machine could print sixteen copies at once instead of eight.

13. We are not justified in supposing that the printing-machine has yet reached its stage of greatest magnitude and completeness. The present machines work so accurately, that inventors are already seeking for further extensions of the same power. Hitherto printing has always been effected on single sheets; but as paper is now made in very long strips, it becomes an interesting question whether the printing could take place before instead of after the cutting of the strips into sheets. Patents have been obtained, since the establishment of the "Times" machine, for three or four contrivances having this object in view.

14. Steam-printing has been here described as if it were only executed by means of cylinders; but such is not the case. Printing-presses, in which the form of type lies flat, and in which the paper is pressed down upon the type by means of a platen, are now moved by steam-power as well as worked by hand. The ingenuity of the late Mr. Cowper was advantageously shown in many inventions relating to these steam-presses.

15. When the printed sheets have been sufficiently dried they are subjected to heavy pressure, partly to equalize

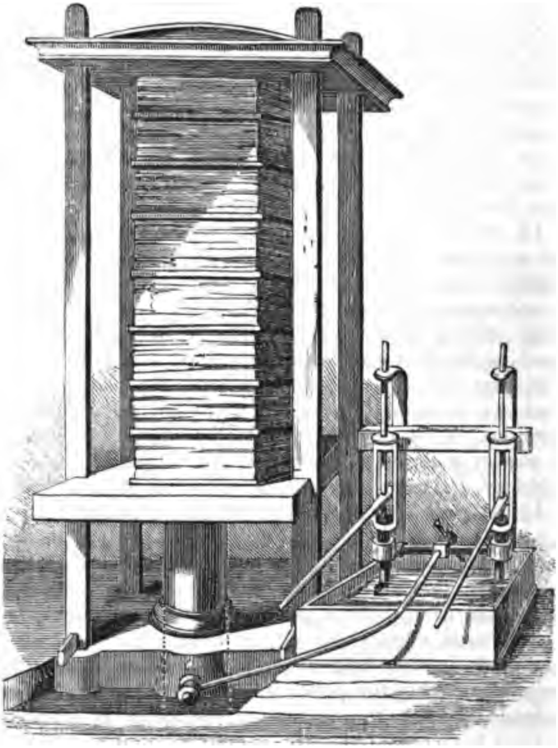

Fig. 7.

the appearance of the two sides of the paper, and partly to produce a glaze or polish on the surface. In the higher-priced works, where additional labour can be paid for, the paper is subjected to hot-pressing; but under ordinary circumstances a vast pile of sheets is subjected to the action of a hydraulic press, such as is shown in fig. 7. In the office of Messrs. Clowes, where the present volume was printed, there is a hydraulic press which will exert a force of nearly 1000 tons—worked by the pressure of nothing more than five gallons of water! The beauty of a printed volume is much dependent on the pressure which the paper thus receives.

LESSON V.

BOOKBINDING.

1. In the present day, the binding of a book illustrates, almost as instructively as the printing, the power of machinery in producing elegant and useful results at a small price. Any one who compares the 'boarded' books of past years with the tasteful and convenient 'cloth gilt' of the present, must at once admit the superiority of the latter, even if there were equality in price; but the cloth-binding of the present day is yet more economical than the inferior paper-binding of earlier times. The shilling and half-crown volumes now so familiar to us, with their strongly-covered and neatly-lettered cloth-binding, could never have been produced without the aid of numerous improvements in the bookbinder's art. The more costly varieties have not undergone an analogous advancement. The old binders could equal anything now produced; for where neither time nor money was spared, the handicraftsman had full scope for displaying taste and refinement.

2. The first matter to be attended to is, to fold the sheets of printed paper. Each sheet, as has been already explained, contains 2, 4, 8, 12, or 16 leaves, or 4, 8, 16, 24, or 32 pages, according as it is called *folio*, *4to*, *8vo*, *12mo*, or *16mo*. Sometimes sheets are printed in still smaller and more numerous pages;

but the above five will suffice for general illustration. Whatever may be the number of pages, the sheet is folded and refolded until brought to the proper book-size. And here it is interesting to see what precision and rapidity are attainable by long practice; the folders—women and girls—are aided by nothing but a paper-knife or folding-stick; and yet they make the folds, exactly midway between the pages of type, at the rate of 300 or 400 sheets in an hour. The greater the number of pages in a sheet, the longer time does the process of folding require. A very ingenious machine has lately been invented by Mr. Black, for folding sheets and newspapers; but the bulk of the work is still, as heretofore, done by women.

3. When the sheets are folded, the collating and arranging into a book are matters of some importance. If there be 1000 copies of a work, and 20 sheets in each copy, it is obviously necessary that all the twenty in any one copy shall be different, and shall succeed each other in proper order. The printer and the bookbinder divide between them the responsibility of ensuring this accuracy. Every sheet, besides the paging, has a mark or *signature* (as it is called) at the bottom of the first page; this signature is generally a letter of the alphabet, and aids in identifying the sheet. In the case above supposed, there would be 1000 sheets having signature A at the bottom, 1000 with signature B, and so on. The printer would either send these sheets to the binder in this state, or he would first gather them into *quires*. A quire consists of one copy of sheet A, one of sheet B, one of sheet C, and so on, until there are sufficient to form the volume; insomuch that there would be as many quires (1000) as there are to be volumes prepared, each quire containing the exact materials for one copy of the work; and the folders and sewers would be careful not to disturb this arrangement.

4. Then comes the important process of *sewing*. If the volume is to be sold cheaply in *boards* or *cloth*, it is sewn immediately after the collating; but all *bound* books are previously pressed or rolled. The bookbinders of olden times were accustomed to hammer the

sheets heavily; but the hydraulic-press and the rolling-press now afford the means of producing the result much more effectively and expeditiously. In the rolling-press the sheets, six or eight at a time, are placed between tin plates, and drawn between two powerful steel rollers; they become smoother and more compressed than by any other method. The sewing is curiously managed. The *sewing-press* is an apparatus having a flat bed or table, two upright bars at the ends, a cross-bar at the top, and two or more strings stretched vertically from the cross-bar to the bed. The sewer, provided with needle and thread, places a folded sheet on the bed of the press; she passes her left arm round to the other side of the press, and, by a series of alternate movements, she sews the sheet to all the strings, passing the string through to the middle fold. She then lays down

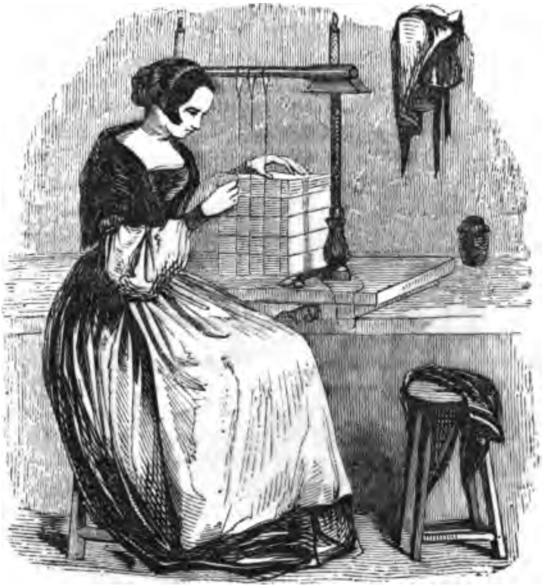

Fig. 8.

a second sheet on the first, and, with the same thread, fastens it in the same way; the strings thus constitute the medium of connexion. All the sheets in succession are thus treated, until the pile contains the proper quantity for a volume. In this manner an industrious woman can sew from 2000 to 3000 sheets in a day.

5. The back of a book has to be rounded, and the edges cut, before the covers are applied. The book is laid flat and is hammered so skilfully that the back edge shall receive a rounded or convex form: the edge has been previously glued, and is hammered before the glue is quite dry, whereby the sheets are enabled to assume and to retain the relative positions given to them by the hammering. The back is again hammered in a different way, to form a kind of groove into which the boards may fit. The top and bottom and front edges are then cut by a machine, the most approved modern form of which is shown in fig. 9. The production of the

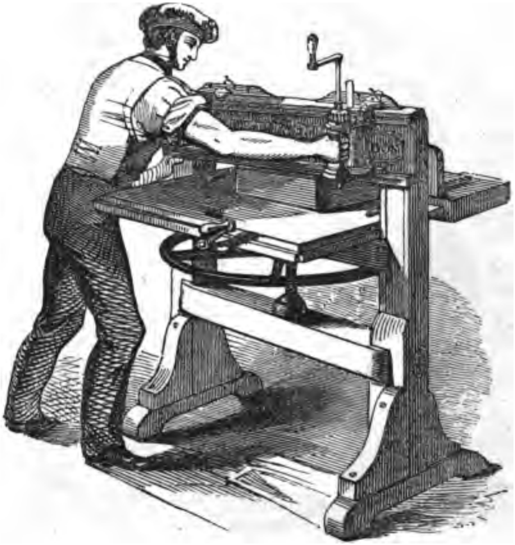

Fig. 9.

concave front edge is managed in a remarkable way; the book is forcibly struck with its convex edge on a table, and brought back to the flat or plane state; the front edge is then cut flat; and when the book is relieved from the press in which it has been held, the back edge springs round into its former convexity, thereby giving a concave form to the front edge. In cheaply-bound books some of the edges may be left uncut, or the back may not be rounded; but the general process is such as is here described.

6. The boards which form the stiff sides of a book are made of millboard—several thicknesses of brown paper pasted and rolled together. If the volume is to be bound, whether in 'calf' or in 'russia,' whether 'whole-bound' or 'half-bound,' holes are made through each board near one edge, corresponding with the strings to which the sheets had been sewn; the strings are passed through the holes, and are glued or pasted down on the inner side of the board. Many niceties of adjustment are necessary here; and when these have been attended to, the cover or leather is applied. The leather is cut to the proper size and shape, and is pasted on the boards and the back edge. If the book be 'half-bound,' the leather is applied first and the paper afterwards. Many bound books have hollow backs;—these are produced by pasting the leather, not upon the back edge of the volume, but upon an intermediate layer of cloth or paper.

7. Before the volume, thus far bound, can be deemed fit for the library or the drawing-room, it requires certain adornments; the production of these adornments is among the prettiest of the bookbinder's operations. The edges are generally either coloured or gilt. The colouring is called either *sprinkling* or *marbling*, according to the manner of effecting it. Gilt-edges, which used formerly to be given only to costly books, are now to be met with in very cheaply-bound volumes: partly owing, it must be confessed, to the use of thinner gold-leaf than is quite consistent with the durability of the glittering ornament. The gilding of the edges is effected while the cover or case

is yet in an unfinished state. The edges are scraped smooth with a sharp piece of steel while held tightly in a press; they are coated with a liquid paint of red chalk and water, and while this paint is still wet, pieces of leaf-gold are applied in sufficient number and shape to cover all the three edges of each book; a little white of egg and water being used to moisten the paint still more effectually. Within a very few minutes after the application of the gold, the edges are sufficiently dry to permit of their being polished with a burnisher of agate, or other hard smooth stone.

8. The covers receive more varied adornments than the edges. In a very cheap book, such as a school-book bound in 'roan' or sheepskin, the leather is sometimes sprinkled or coloured in a very simple way, without any other attempt at decoration; but most bound books have more or less *blocking* or *tooling*, by which some kind of sunken device is produced. Tools of various shapes, made of metal, are heated to a certain temperature, and are pressed against the leather of the book; the pressure and the heat produce a sunken, darkened, polished mark, which may form part of any fanciful device, according to the shape of the tools employed. Leaf-gold may or may not be employed in this process.

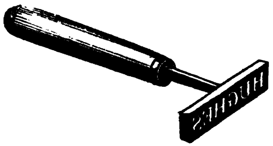

Fig. 10.

9. Interesting as are these processes relating to handsomely-bound volumes, the production of cloth-binding is commercially more important, since it has been one of the means whereby the greater diffusion of literature has been rendered possible. Cloth-binding has had more to do with this matter than is perhaps generally supposed; for it enables us to place upon our book-shelves a neat volume, at a price exceeding only by a few pence the value of the unbound sheets. When a volume is 'bound in cloth' the cloth cover is pasted to the boards before the latter are attached to the book, and the case thus made is fixed to the volume

chiefly through the medium of the blank papers pasted in the inside of the covers. There is frequently, also, a strip of canvas pasted along the back edge, which aids in the fastening of cheaply-bound books.

10. Nothing has produced a greater improvement in the appearance of new books than the elegant manner in which the cloth covers are now gilt and embossed. Formerly a book published 'in boards' became so soiled and unsightly after a little use, that it was unfitted to occupy a place in a bookcase until it had been rebound; but a modern volume, published in 'cloth gilt,' has a neatness of appearance which fits it to occupy a place beside well-bound volumes. The cloth is woven of cotton, at Manchester, expressly for the bookbinders; it is dyed and glazed in London and other towns, and is sold to the bookbinders in yard-wide rolls. The device to be impressed on the book is engraved upon a metal block, and is stamped upon the cloth covers by means of a powerful press, gold being previously applied, or not, according to the richness of the ornamentation. Some cloth-bound books, without any particular richness of decoration, have a small neat pattern embossed all over the surface of the cloth; this is produced by drawing the cloth between two metal cylinders, of which one is heated from within by gas, and of which both are engraved on the surface with the required device. As a third variety, the cloth for books is sometimes stamped with an embossed device by means of a press, instead of being drawn between rollers before its attachment to the boards of the volume.

11. A remarkable variety in the art is the production of *India-rubber* binding, remarkable in so far as it illustrates the powerful cementing qualities of that gum. The sheets are not sewn to strings in this kind of binding; they are cut on all four edges, and separated into single leaves. The back edge is rounded by means of a simple contrivance, and a coating of liquid India-rubber is applied; this cements the leaves well together, at the same time that it affords to the volume a remarkable facility in opening and lying flat on a table. It is a very convenient mode of binding for thick volumes.

12. It may not be uninteresting to the reader to examine the volume now in his hand; many of the little contrivances for imparting strength and neatness to a cloth-bound book may perhaps be rendered intelligible by such an examination.—George Dodd.

* * *

THE PRINTER'S SONG.

Print, comrades, print! a noble task
  Is the one we gaily ply;
'Tis ours to tell to all who ask
  The wonders of earth and sky.
We catch the thought, all glowing warm,
  As it leaves the student's brain;
And place the stamp of enduring form
  On the poet's airy strain.
    Then let us sing, as we nimbly fling
      The slender letters round:
    A glorious thing is our labouring,
      Oh, where may its like be found?

Print, comrades, print! the fairest thought
  Ever limned in painter's dream;
The rarest form e'er sculptor wrought
  By the light of beauty's gleam;
Though lovely, may not match the power
  Which our proud art can claim—
That links the past with the present hour;
  And its breath—the voice of fame.
        Then let us sing, &c.

Print, comrades, print! God hath ordain'd
  That man by his toil should live;
Then spurn the charge that we disdain'd
  The labours that God would give!
We envy not the sons of ease,
  Nor the lord in princely hall,
But bow before the wise decrees
  In kindness meant for all.
        Then let us sing, &c.

Natural Philosophy.

BY JOHN TYNDALL.

LESSON I.

MECHANICAL PROPERTIES OF LIQUIDS.

1. *What constitutes a Liquid.*—Matter is presented to us in three different forms, the solid, the liquid, and the gaseous or aeriform. No one of these forms is constant: by the application of heat the solid form may be converted into the liquid or gaseous, and by the application of cold, liquids, and even gases, can be converted into the solid condition. Although there is no difficulty in distinguishing liquids from solids or gases when we see them, still it is not very easy to define in a scientific manner what a liquid really is. In books on natural philosophy we usually find it stated that the molecules of a liquid body have no tendency, like those of a solid, to cohere, and that they are separated by the least force applied to them. But this can scarcely be accepted as a correct definition; for the following reasons:—

2. Every boy knows what a soap-bubble is, and that when the pipe from which it is blown is inverted, a drop, sometimes a large one, depends from the lower portion of the bubble. Now when we compare the weight of this drop with the thinness of the film which supports it, we must come to the conclusion that the strength of the film, or in other words, the force by which its particles cohere, is really very great. But it may be urged, that the film referred to is not one of water, but of soap mixed with water: there is, however, every reason to believe that the soap merely serves to diminish the *mobility* of the particles, without increasing their cohesion.

3. But we do not need soap to prove the strong cohesive force of liquids: if water be boiled for a long time so as to expel the air which it always holds in solution, the cohesion of the particles becomes so great that you can fill a long tube with the liquid, turn it upside down,

and the column of liquid will remain fixed in the tube, supported by its own cohesion. Water thus prepared, when enclosed in a vessel void of air, requires a far greater heat to make it boil, or in other words to tear its particles asunder so as to cause them to assume the form of steam, than ordinary water; and when it does boil, we do not find it commencing by a gentle ebullition, but suddenly, as if a spring were broken, the cohesion is overcome, and the heated water explodes like gunpowder.

4. We probably obtain a more correct notion of the nature of a liquid than that commonly entertained when we imagine its particles perfectly free to *slide* over each other in every direction, though the force which resists the tearing asunder of the particles may be very great. According to this view it is not the absence of cohesion, so much as the absence of *rigidity*, which distinguishes the liquid condition.

5. *Liquids transmit pressure equally in all directions.*—The most remarkable property of liquids is the power which they possess of transmitting pressure equally in all directions. Let A B C D, fig. 1, represent the section of a cubical vessel with tubular apertures in its sides. Into these tubes let the pistons *a*, *b*, *c*, *d*, fit watertight, and let the vessel be filled with water until the surface of each piston shall be in contact with the liquid. If the piston *a* be now pressed downwards with any force, say the force of one pound, this pressure is not only transmitted to *c*, which is vertically under *a*, but also to *b* and *d*. If the pistons be all of the same size, it would require a force of a pound at *b*, *c* and *d*, to prevent these pistons from being forced out. Now, no matter where we may suppose our pistons to be placed, the same effect would

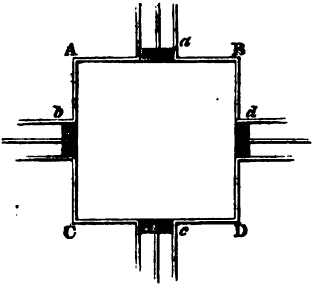

Fig. 1.

follow: so that if the piston *a* present an area of one square inch, a weight of one pound at *a* would produce a pressure of one pound on every square inch of the interior surface of the vessel.

6. If the pistons be not of the same size—if the area of *d*, for example, be two square inches instead of one—then a force of one pound acting on *a* would produce a pressure upon *d* equal to two pounds. In this case therefore a force of two pounds would be required at *d* to prevent the piston from being forced out.

This is a point of considerable mechanical interest, and it is therefore important to make it perfectly clear. Let A B C D, fig. 2, be a closed vessel having two cylinders C and D of unequal sizes passing through the top. Into these cylinders let the pistons *a* and *b* fit water-tight: suppose the area of *a* to be one square inch, and of *b* to be five hundred square inches: then if a force of one pound be applied at *a*, a pressure of one pound will be exerted on every square inch of the interior of the vessel, and hence a pressure of 500 lbs. will act upon the under surface of the piston *b*. To prevent the piston from being forced upward, a weight of 500 lbs. must be placed upon it. If, while things are in this state, an additional force of a pound be applied at *a*, the weight of 500 lbs. will be thereby lifted.

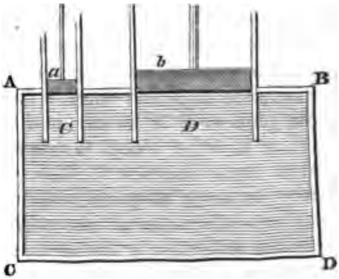

Fig. 2.

7. *The Hydrostatic Paradox.*—The fact of so small a force being able to raise so large a weight has given to the experiment which we have just described the name of the hydrostatic paradox; but let us examine wherein this paradox consists. When the piston *a* descends, it is true the piston *b* is raised; but *how much* is it raised? Suppose *a* to be pressed downwards

through the space of 1 inch; a column of water which fills this space will be forced into the cylinder *b*. But as *b* is 500 times the area of *a*, the little column will fill only the $\frac{1}{500}$th part of an inch of the cylinder *b*; that is to say, when the piston *a* is pushed down a full inch, the piston *b* rises only $\frac{1}{500}$th of an inch. Now the magnitude of the effect produced must be estimated by the height to which the weight is lifted, and we see that although the *weight* is very great the *height* is very small, the space passed through by the large piston being to that passed through by the small one in the inverse proportion of the area of the former to that of the latter. These considerations show that the experiment is in reality no paradox at all.

8. It is indeed no more a paradox than an experiment which boys make every day with a see-saw; for here it is well known that any boy, however small, may be made to balance any boy however large. I will ask you to imagine a see-saw, each of whose arms measured from the centre is 500 feet long. Let a boy one pound in weight be conceived to sit upon the extreme end of the plank, or in other words 500 feet from the centre; the chapter upon levers will show you that this boy will exactly balance another weighing 500 pounds, and sitting at a distance of *one foot* from the centre. Of course the weight and distances here supposed are quite absurd, but I choose them because they are the same as those used in the case of the "paradox." Here, then, we have a weight of 1 lb. exactly balancing a weight of 500 lbs.; and if while things are in this balanced condition a pound weight be placed in the hand of the small boy, he will sink and lift the other. But if we observe the space through which both boys pass, we shall find that the small boy must descend through 500 inches in order to lift the large boy 1 inch: it is evident that the case is very similar to that of the hydrostatic paradox.

9. *The Hydrostatic Bellows.*—If instead of placing a pound weight upon the piston *a*, fig. 3, we poured one pound weight of water upon it, the effect would of course be the same; and it is manifest that the result

would be in no way altered if the piston *a* were entirely removed, and the water simply poured into the tube which contains the piston; the liquid thus poured in would raise the piston *b*. This principle is applied in the construction of the hydrostatic bellows, a sketch of which is given in fig. 3. The bellows are made like those of an accordion or concertina. A and B are boards which are united by flexible leather: at T a tube is inserted which is bent upward to U. On the board A weights are placed, and into the tube U T water is poured: this water enters the bellows and raises the weights.

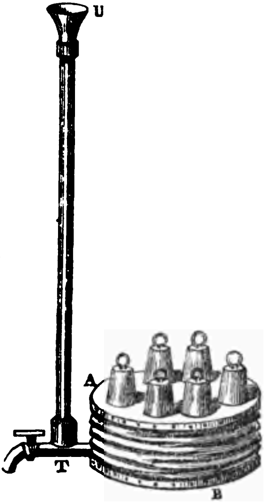

Fig. 3.

10. Let us now suppose the two cylinders C and D, fig. 2, to be prolonged to the bottom of the vessel so as to form two separate cylinders, as shown in fig. 4, and let these two cylinders be united by the open passage *p*. It is evident that all that has been said regarding fig. 2 applies also to fig 4. When *a* is pressed down, the water will be forced through *p* into the other cylinder; so that a pressure of a pound at *a* will, as before, produce a pressure of 500 lbs. on *b*.

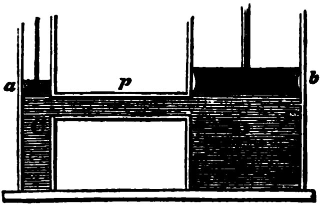

Fig. 4.

11. Another step carries us to the construction of the well-known hydraulic press, or Bramah's press, as it is sometimes called, which I hope you will now find

little difficulty in understanding. A simple form of the machine is sketched in fig. 5. C and D represent

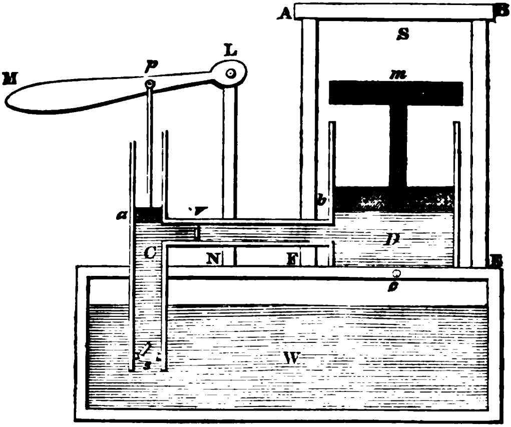

Fig. 5.

two cylinders as before; C however now dips into a cistern of water W, while D terminates at the top of the cistern. N L is a strong upright to which the lever L M is attached by a pivot at L: a pin *p* connects this lever with the piston *a* of the small cylinder, and it is evident that by raising or lowering the end M the piston may be caused to ascend or descend. At *v* in the cross passage is a valve which opens towards D, and at *s* at the end of the small cylinder is another valve which opens downwards. Attached to the piston-rod of *b* is a strong metal plate *m* which, of course, rises and sinks with the piston underneath. A B E F is a strong framework, the top A B of which represents the section of a second strong metallic plate.

12. We will now describe the action and use of this instrument. When the piston *a* is raised, it is plain that the water will follow it through the valve *s* as in the case of a common pump. When the piston ceases to ascend, the valve *s* falls by its own weight, and thus prevents the water from returning to the cistern W. When therefore the piston *a* is pushed downwards, the

water is forced through the valve *v* into the cylinder D, and is prevented from returning by the closing of *v*. On raising the piston again, the valve *s* opens and the cylinder C is filled with water, which by the descent of *a* is forced into the cylinder D as before. It is evident that by a succession of plunges we gradually raise the piston *b* and the plate above it, and that if any body be placed in the space A, it may be forcibly squeezed between the plates A B and *m*. If, as already supposed, the piston *b* be 500 times the area of the piston *a*, then a pressure of 50 lbs. exerted on *a* will produce a pressure of 2,500 lbs. on *b*; and hence is capable of pressing the body placed above *m* with a force of 2,500 lbs. I have intentionally made the figure as simple as possible, it being my object to make the principle perfectly clear; in practice the machine is variously constructed, but if the pupil understands the above description thoroughly, a little reflection will enable him to master the most complicated machines of this description. At *c* there is a cock through which, when it is required to empty the cylinder D, the water flows back into the cistern.

LESSON II.

PRESSURE AND DISPLACEMENT.

1. *Pressure of a liquid on the sides and bottom of its containing vessel.*—If a cubical vessel contain a solid mass which fills it exactly, the sides of such a vessel may be removed, while the mass within it retains its position, and presses with all its weight upon the bottom of the vessel. The sides do not at all contribute to sustain the mass, and whether they are present or absent, is a matter of indifference. If, however, the same vessel be filled with a liquid, the sides are necessary to preserve the shape of the mass; the liquid exerts a pressure upon the sides, and if the latter were removed would inevitably flow away in all directions. It is evident, however, that the sides, being vertical, do not contribute to the support of the weight of the liquid, but that, just as in the case of the solid body, the bottom of the vessel bears all the weight. The pressure, then, upon the bottom of any vessel with upright sides is equal to the weight of the liquid within the vesse

2. Now it is a singular consequence of the property possessed by liquids, of transmitting pressure in all directions, that the pressure upon the bottom of a vessel of any shape whatever is equal to that exerted on the bottom of a vessel with upright sides, provided only that the bottom of the latter is of the same area as that of the former, and that both vessels are filled to the same height with liquid. This is proved by means of the apparatus sketched in fig. 6. A B C is a bent tube, furnished at A with a collar, on which vessels of different shapes may be screwed water-tight. Supposing the tube to be filled with mercury up to A, the mercury will stand at the same level C in the opposite arm of the tube. The point C being carefully marked, let the cylindrical vessel *g* be screwed on to A. If water be now poured into *g*, say to the height *h*, it will cause the column in the other branch of the tube to rise to *k*, the ascent being evidently due to the pressure of the water upon the surface of the mercury underneath. The point *k* being carefully noted, let *g* be now removed, and let the vessel *m* or *n* be screwed on to A; let water be poured into it until the height of the surface of the water above that of the mercury at A is the same as it was in the last experiment. On observing the other branch of the tube, it will be found that the height through which the column has been elevated is exactly the same as before; *k* will mark the summit of the column.

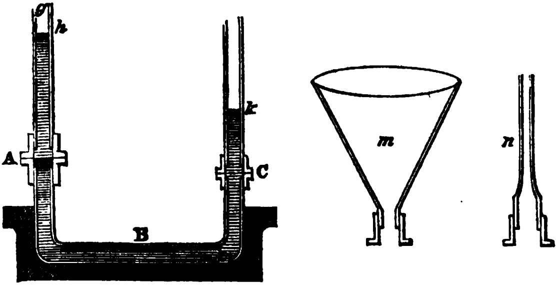

Fig. 6.

3. Hence we see that the pressure upon the bottom

is influenced only by the *height* of the liquid column and the area of its base. The pressure on the bottom of any vessel, no matter what may be its form, is always equal to the weight of a cylinder of the liquid, with a base equal to the bottom of the vessel, and a height equal to the height of the water within it. The pressure is wholly independent of the *quantity of water* as long as the bottom is of the same size, for we have seen that the bottom of the vessel *m*, fig. 6, sustains precisely the same pressure as that of *n*, although the quantities of water which the vessels contain are very different. It is thus evident that by suitably choosing the shape of a vessel we may produce an enormous pressure with a single pint of water. Supposing, for example, that we choose a vessel with a square bottom, which measures 4 inches every side, the area of this bottom is 16 square inches; and if the vessel be so narrowed upwards that when the pint of water is poured into it the surface shall be two feet above the bottom, the pressure borne upon the bottom in this case will be fully fifteen pounds, for this is the weight of a cylinder of water whose base is 16 inches and height 2 feet.

4. We here see very clearly the explanation of an experiment cited in some old treatises on natural philosophy, and which at first sight seems very startling. A strong cask *a* was filled with water, and through the cask was introduced a long tube *c d*; on pouring water into the narrow tube, the cask being unable to resist the pressure thus produced, burst asunder. Supposing such a tube to be 18 feet long, and to possess a section of 1 square inch; when filled to the top with water, the pressure of the liquid cylinder at the point *c* would be equal to its weight, which is about 8 pounds. This pressure would be transmitted to every square inch of the interior sur-

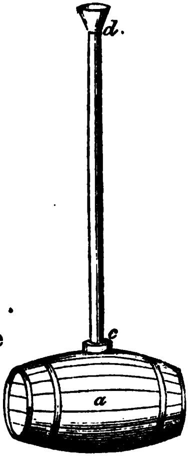

Fig. 7.

face of the cask, and supposing the number of square inches to be 7000, which is quite within ordinary bounds, to preserve itself from bursting, the cask must be able to bear a pressure of 56,000 lbs.; this enormous effect being produced by the judicious disposal of a very small quantity of water.

5. The pressure of a liquid is not, however, confined to the sides and bottom of the vessel which contains it, but every portion of the liquid mass itself sustains a pressure which depends upon its depth below the surface. A flat fish, for example, swimming at a depth of 32 feet below the surface of the sea, sustains the downward pressure of a column of water whose base covers the fish, and whose height is 32 feet. If the back of the little fish be 12 square inches in area, it will, at this depth, exist under a downward pressure of 180 pounds, and it may be asked, why does not the animal sink under this pressure? The reason is, that the fish is pressed as much upwards by the water as downwards, and these two opposite pressures balance each other, so that the fish moves as if it suffered no pressure at all. The fish being thus squeezed, it may however be asked, why it is not crushed to pieces? the reason is, that the tissues and liquids which constitute the body of the fish exert a pressure against the surrounding water equal to that which it exerts against them. The materials of which the fish is composed are, like the water itself, almost perfectly incompressible. Some fish, indeed, are furnished with air-bladders, and when such fish swim at great depths, the bladders are very much compressed; the consequence is, that when suddenly removed from those depths by the hook of the fisherman, the air-bladder swells like a balloon, and thus causes the appearance which we observe at the fish-stalls, where the stomach of a fish is often seen forced through its mouth by the distension of the air within its body.

6. *Compressibility of Water.*—In connexion with this portion of our subject it may be asked whether water itself is not much compressed at very great depths. So small is the compressibility of water,

that it was for a long time believed to be absolutely incompressible. An experiment was once made in Florence which is very celebrated in the annals of science. A hollow sphere of gold was filled with water and carefully closed. Now it is a geometrical fact that a sphere takes up more space than any other body which posseses a surface of the same area; hence if a hollow sphere be caused to change its shape, without either stretching or shrinking, the new shape will occupy less space than the old one. The aim of the Florentine experimenters was to squeeze their sphere of gold so as to make it change its shape, for they knew if this were effected, that the water within the sphere would be compressed into a smaller space. They found, however, that they could not change the shape of the sphere, although the pressure applied was so great as to cause the liquid to ooze through the pores of the gold, and to collect like dew upon its surface. A similar effect was observed very recently in Manchester, during some experiments made to determine the influence of pressure upon the melting points of solids. Melted spermaceti contained in a brass cylinder was subjected to a pressure so great that the liquid was forced in invisible jets through the pores of the brass until the cylinder was quite emptied of its contents.

7. It is now known, however, that liquids are compressible in a small degree, and various instruments have been constructed to demonstrate the fact. Perhaps the simplest proof is the following:—A vessel *d*, fig. 8, carefully filled with water, has a solid plunger *p* entering through its neck; on the plunger, and immediately in contact with the mouth of the vessel, a ring is fitted so as to be capable of being pushed along the plunger, still clasping the latter so tightly as to remain in any position in which it is placed. Such a vessel was sunk to a great depth in the sea, and on being raised again, it was found that the ring had been moved, and stood at some distance above the mouth of the vessel. This proved that the plunger

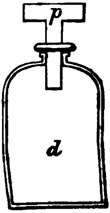

Fig. 8.

had been forced into the vessel below, or, in other words, that the water within the vessel had been squeezed into a smaller compass: when the vessel was drawn up, the liquid within it, being relieved from the pressure, resumed its former dimensions, and forced out the plunger which carried the ring along with it.

8. *Principle of Archimedes.*—We now proceed to consider a point which has a great traditional interest connected with it. It is reported that Hiero, king of Syracuse, having given a quantity of gold to a goldsmith to make him a crown, suspected that the man had substituted for a portion of the gold a baser metal, and that the crown returned to him, although of the proper weight, was not of the proper material. He asked Archimedes, one of the most celebrated characters of antiquity, to determine whether his suspicions were correct. It must be remembered that in those days people knew nothing of the tests which would now render the solution of the problem a very simple matter, and that it was therefore a question of exceeding difficulty: but a problem must be very difficult indeed which resists the continued application of the human mind; for such application is almost always rewarded by the streaming in of light, even from unsuspected quarters. Archimedes found this to be the case. While pondering upon the subject, he chanced to enter a bath which had been filled brim full of water, and observed, as he entered, that the liquid flowed over the edge. Prepared by the mental discipline which he had previously gone through, the solution of the problem at once flashed upon him, and it is related that he sprang in ecstasy from the bath, and ran through the streets of the city, crying, "Eureka! Eureka!" "I have found it! I have found it!" We will now consider how the simple circumstance to which we have referred could have proved so instructive as to make the great ancient philosopher almost mad with joy.

9. By comparing a shilling with a sovereign, any boy can satisfy himself that gold is much heavier than silver—indeed, it is nearly twice as heavy. A pound of silver is therefore larger than a pound of gold, and if

immersed in a vessel accurately filled with water, the former will cause nearly twice as much water to flow over as the latter. If a mixture of gold and silver of the same weight were immersed, the quantity of water displaced would be something less than that displaced by pure silver, and something greater than that displaced by pure gold; and here was the secret of the test of Archimedes. He took the king's crown, and procured a quantity of pure gold of the same weight; he immersed the crown and the gold successively in water, and found that the crown displaced more of the liquid than the gold did. The problem of the king was thus solved, and the dishonesty of the astonished goldsmith completely demonstrated.

10. But we have not yet derived all the instruction possible from this important discovery, and this we must endeavour to do. When a bather walks in water which reaches to his chin, he finds that the soles of his feet press very lightly upon the bottom; a portion of his weight is borne by the water; if it were deep enough to reach a little above his eyes, his whole weight would be borne by the liquid, and the bottom would not be at all necessary for his support. Hence it is that a person finds it easy to lift a mass of stone under water, which, when he brings it to the surface, altogether surpasses his strength, and that a body weighed in water appears to lose a considerable portion of its weight. The question now is—how much of its weight does the body lose? How much of its weight is the water able to support?

11. When a lead bullet is immersed in water, it displaces a sphere of water exactly equal to the bullet in size: imagine such a sphere of water in the midst of a mass of the liquid: it is evident that the sphere is borne by the water, and neither sinks nor rises. Hence when the lead bullet occupies the place of the sphere, a portion of its weight, equal to the weight of a sphere of liquid of the size of the bullet, must be borne by the water. This leads us to the statement of the most important principle of hydrostatics, called the principle of Archimedes, namely, *that a body immersed in a liquid*

loses a portion of its weight equal to the weight of the quantity of liquid which it displaces.

12. If what I have here stated should be found difficult to understand, the difficulty will disappear when we go through the experimental proof of the principle. Let a *hollow* cylinder, *c*, be attached to one arm of a balance, fig. 9, and to this let another *solid* cylinder, *p*, be attached, of such a size as accurately to fill the hollow cylinder placed above it. By placing weights in the opposite scalepan, the balance-beam may be brought into a horizontal position; and when this is accomplished, let the cylinder *p* be caused to dip into a vessel of water. The equilibrium is now destroyed; *p* loses a portion of its weight, and consequently the end of the balance to which it is attached is raised by the weights in the opposite scalepan. The question now is, how much of its weight has *p* lost? or, more correctly, how much of its weight is borne by the water? Let water be poured into the hollow cylinder *c*, and it will be found that when the cylinder is full of water the balance-beam stands once more exactly horizontal. The weight, therefore, lost by *p* is exactly made good by the weight of a mass of water equal in size to *p*, and this is the experimental proof of the principle of Archimedes.

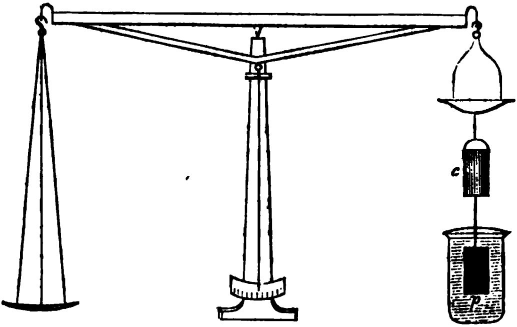

Fig. 9.

LESSON III.

SPECIFIC GRAVITY.

1. We shall now see the utility of the principle which we have just established. It is of course of the highest practical importance to be able to compare the weights of different substances with each other. This might be accomplished by reducing the substances to the *same size*, and then weighing them in the ordinary manner; in this way it would be found that if the weight of a cube of silver be 10 grains, or 10 ounces, or 10 lbs., the weight of a cube of gold, of the same size, would be very nearly 19 grains, 19 ounces, or 19 lbs. It would, however, be a work of great difficulty, and indeed, in many cases impossible, to reduce bodies to the same dimensions, and hence the principle of Archimedes comes in to our assistance. Supposing a body which weighs 6 ounces to lose 2 ounces of its weight in water, the principle referred to teaches us that these 2 ounces are the weight of a mass of water of the same size as the body immersed, and hence the weight of this body would be *three times* that of water. In like manner, supposing the weight of a body of 27 ounces to be reduced to 24 ounces in water, we know that the difference, 3 ounces, would be the weight of a bulk of water equal to that of the body; and hence the latter must be regarded as 9 times heavier than the former. Calling the weight of water 1, the weights of the two bodies last alluded to would be represented by the numbers 3 and 12; and these numbers, 1, 3, and 12, are called the *specific gravities* of the substances to which they correspond. In the determination of specific gravities, the weight of distilled water, at a certain temperature, is usually taken as a standard, and represented by the number 1; and when in printed tables we find the specific gravity of gold stated to be 19·26, and that of silver 10·47, it is understood that the specific gravity of water is unity. Reflecting on what has been said, the reason of the following practical rule will be evident:—*Divide the real weight of the body by the*

weight it loses in water; the quotient will be the specific gravity.

2. In order to illustrate the foregoing, and to prepare us for what is yet to come, we will here propose a few exercises.

Example 1. A body, weighing 52 lbs., loses 13 lbs. of its weight in water; another body, weighing 16 lbs., loses 2 lbs. of its weight in water; what ratio does the weight of a cubic inch of the former substance bear to the weight of a cubic inch of the latter?

A cubic inch of the former body is readily found, by the method we have just described, to be equal in weight to 4 cubic inches of water, while a cubic inch of the latter body is found, by the same process, to be equal in weight to 8 cubic inches of water; it is, therefore, plain that a cubic inch of the first body weighs only half as much as a cubic inch of the second.

Example 2. A body, weighing 25 lbs., loses, when immersed in water, 5 lbs. of its weight. It is then joined to a second body weighing 12 lbs.; and it is found that the compound body, formed by the union of both, loses 9 lbs of its weight in water: required the specific gravity of the second body?

Here we find the weight of a mass of water equal in bulk to the first body to be 5 lbs.; and the weight of a mass of water equal in bulk to both bodies together equal to 9 lbs. Deducting 5 from 9, we find the weight of a mass of water, equal in bulk to the second body, to be 4 lbs.; but the weight of the body itself is 12 lbs., and consequently, dividing 12 by 4, we obtain its specific gravity = 3.

Example 3. Let everything remain as in the last question, except that the compound body loses 20 lbs., instead of 9 lbs., by immersion; required the specific gravity of the second body?

Here, as before, the weight of a mass of water, equal in bulk to the first body, is 5 lbs., and the weight of a mass, equal in bulk to the compound body, is 20 lbs.; deducting 5 from 20, we find 15 lbs. to be the weight of a mass of water equal in bulk to the second body. But the weight of the body itself is 12 lbs., and consequently its specific gravity, found by dividing 12 by 15, is $=0{\cdot}8$.

3. In our first illustrations we intentionally restricted ourselves to those bodies which are *heavier* than water, and which therefore *sink* in the liquid; but the last example reveals to us the method employed when the specific gravity of a body *lighter than water* is sought. The body is attached to a second one of such a density that both together sink in water, and the precise steps indicated by the question are pursued.

4. In the determination of the specific gravity of liquids, the difficulty of reducing the bodies to the same dimensions disappears. The method pursued by chemists, who aim at very accurate determinations, is to provide a small glass flask with a ground-glass stopper, and ascertain the precise weight of the quantity of liquid which the flask is able to contain. Filling the flask, first with water, and afterwards with the liquid whose specific gravity is to be determined, we can compare the weights together, and thus obtain the specific gravity sought. There is another way, however, of determining the specific gravities of liquids, which depends upon the principle that the denser a liquid is, the *less deeply* will a floating body sink in it. Salt water being heavier than fresh, a floating body will not sink so far in the former as in the latter, a fact well known to those who are accustomed to swimming in rivers and in the sea. In sulphuric acid a floating body will sink to little more than half the depth that it sinks to in water; and many bodies which sink *wholly* in the latter continue floating in the former. Mercury is a still more striking example of the influence of density, for iron will float upon it just as wood floats upon water.

5. The *whole weight* of a floating body is borne by the liquid in which it floats, and the weight of the liquid it displaces is exactly equal to the weight of the body. A piece of wood, weighing 5 ounces, displaces 5 ounces of the liquid which supports it; it will displace 5 ounces of water, or 5 ounces of alcohol; but as water is heavier than alcohol, the latter 5 ounces will be larger than the former, and consequently the body

must sink deeper in alcohol than in water. It is easy to see that the specific gravities of two liquids are inversely proportional to the quantities of them displaced by the same floating body; if the quantity displaced, or, in other words, if the bulk of the immersed portion of the floating body in one liquid be twice what it is in the other, the specific gravity of the former is evidently one-half that of the latter.

6. To ascertain with precision the quantity of liquid displaced by the floating body, a shape is given to it similar to that sketched in fig. 10. G is a hollow globe, to which, on the one side, a tube, *c*, of uniform thickness, is attached, and which is united on the other with a vessel, *v*, in which a quantity of mercury is enclosed. The use of the mercury is to cause the instrument to stand upright in a liquid, and its quantity is so regulated that when the instrument is immersed in the heaviest liquid which it is destined to test, the hollow ball shall be barely covered by the liquid, while when it is immersed in the lightest liquid which it is intended to test, the stem *c* also shall be nearly submerged. Supposing the volume or bulk of the instrument up to the point where the stem is cut by the surface of the heavier liquid to be expressed by the number 1000, and the volume up to the point where the stem is cut by the surface of the lighter liquid to be 1100, it is evident that the specific gravities of the two liquids are to each other in the inverse ratio of these numbers, and supposing the lighter liquid to be water, the specific gravity of the heavier one would be 1·1. If we divide the interval between the two points alluded to into a number of equal parts, it is plain that by observing the point at which the surface of any liquid cuts the stem, we can ascertain the specific gravity of the liquid. In practice the stem is so graduated that the specific gravity can be at once read off.

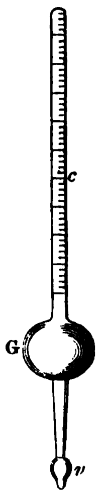

Fig. 10.

There are various mechanical contrivances for the determination of the specific gravities of solid and liquid bodies; but if the pupil understand the principles which we have endeavoured to expound, he will find little difficulty in comprehending such contrivances, or indeed in adding to them new inventions of his own.

LESSON IV.

MECHANICAL PROPERTIES OF AIR.

1. Both liquids and gases are comprised under the more general term *fluids*. The Germans have no single word answering to our word liquids, and they distinguish liquids from gases, by calling the former "droppy fluids"—fluids capable of being poured out into drops like water, and *elastic fluids*, of which air is a type. If you compress air, you will find that it resists, and on removing the pressure, it expands again to its former size. Air is elastic because of the mutual repulsion of its particles; if the volume of a vessel containing a given quantity of air be doubled, this repulsion will cause the air to expand and fill the vessel. Here a reflecting boy may ask why it is that the atmosphere is not dissipated by this elastic force, since the atmosphere is enclosed in no vessel, and has free space to diffuse in. The reason is, that the earth is within the atmosphere, and holds the latter swathed round it by the force of gravity, which acts in opposition to the force by which the particles of air mutually repel each other.

2. The atmosphere is in fact an ocean of gas, which encompasses the earth. We have seen in the case of liquids, that at great depths, the water of the sea is compressed into a smaller space: this holds true in a far more striking degree in the case of air. The air near the surface of the earth, or in other words near the bottom of the air-ocean, is far more dense than at some elevations which even man has attained. Had De Luc, or Gay Lussac, or Mr. Walsh, in his recent balloon ascent, taken with him a bladder half filled with air from the earth's surface, he would have found that before his highest elevation was attained, the air would have filled the bladder. Being relieved from the weight of a

stratum of dense air, eighteen or twenty thousand feet in thickness, the elastic force of the air within the bladder would cause it to expand, until at length the air would press against the sides of the bladder and distend it.

3. But does the air possess weight? Most certainly; as may be proved in the following manner:—Let a flask A, fig. 11, exhausted of air, be suspended from one end of a delicate balance; and let weights exactly sufficient to sustain the flask be placed upon the opposite scalepan. If the cock *c* be now opened, the air will enter the flask A, and the moment it does so, the flask will sink, thus demonstrating the weight of the air which has entered it.

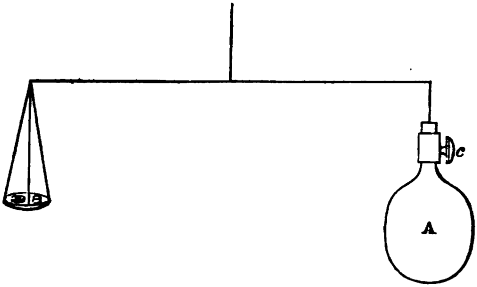

Fig. 11.

4. *Pressure of the Atmosphere.*—The air being thus proved to possess weight, the atmosphere under which we live must exercise a certain pressure on the earth's surface, and on all things upon that surface. This is the case. Conceive a column of air with a base of one square inch, extending from the surface of the sea to the top of the atmosphere; such a column would weigh about 15 lbs., and consequently would exert a pressure of 15 lbs. on the square inch of surface which supports it. For this reason an amount of pressure equal to 15 lbs. per square inch is called *an atmosphere;* 30 lbs. per square inch, two atmospheres; 45 lbs. per square inch, three atmospheres, and so on. As in the case of liquids, the pressure is equal in all directions: every square inch of the human body bears a pressure

of 15 lbs., and hence the total pressure upon a full-grown man must amount to several tons. Why then are we not crushed? our answer must be the same as that already given in allusion to fish at great sea depths. The solids, liquids and gases of the human body exert an outward pressure which exactly balance the inward pressure of the atmosphere.

5. *Discovery of the Weight of the Atmosphere.*—The discovery that the atmosphere possesses weight is a very celebrated one. Before the time of Galileo, a man eminent in science, and who was chiefly instrumental in overturning the system of false philosophy which was prevalent in his day, it was never thought that the air possessed weight. Pumps had been used; but nobody seemed to entertain the idea that there was any limit to the height to which water could be raised by a pump. I will here give a very brief description of this machine. A B, fig. 12, is a tube, one end of which, B, dips into water: into the tube a piston *p* is fitted air-tight, and can be pushed downwards or raised upwards by means of a handle attached to the rigid rod *c d*. Through the piston a passage is bored, and this passage is closed at times by a little door or *valve*, which can only open upwards. Conceive first the space immediately below the piston to be filled with air: when the piston is pushed downwards, the air below it will lift the valve and escape: when the downward motion ceases, the valve falls by its own weight. If now the piston be drawn up, the valve being closed, no air can reach the space below it; the space, if it remained empty, we should call a *vacuum*. But it does not remain empty; for, as the piston

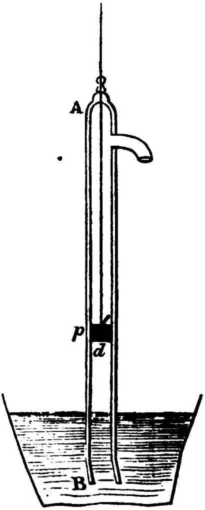

Fig. 12.

ascends, it is followed by the water; and when the piston descends again, water instead of air rushes through the valve and gets above the piston. On raising the piston again, this water is lifted, for it cannot return through the valve, and finally escapes through the spout of the pump.

6. In this experiment the piston appears to *suck* the water after it, and hence the name of sucker which is sometimes applied to this portion of the machine. Before the time of Galileo, it was never thought that there was a limit to the height to which water could thus follow the so-called sucker. Some gardeners in Florence chanced to sink a very deep pump, but found to their great astonishment that they could not get the water to rise to a greater height than 32 feet. The explanation given by the philosophers of those days of the ascent of water in a pump was, that *nature abhorred a vacuum*, and that hence the water rushed in to fill the empty space created by the ascent of the piston. By this pompous language they deceived themselves, and hid their ignorance under a figure of speech; nevertheless, the explanation was sufficient to satisfy the world for two thousand years. The gardeners in their difficulty came to Galileo, and he, old man, embittered by the persecutions he had suffered for declaring the truth and opposing error, replied sarcastically to his questioners: "It is evident that nature abhors a vacuum only to the extent of 32 feet." He did not however solve the problem: this was reserved for his pupil Torricelli to accomplish.

7. Torricelli reasoned thus:—These 32 feet of water must be *lifted* by something. Their weight is the measure of the force which lifts them: what can this force be? Perhaps the atmosphere has weight, and that it presses upon the surface of the water without the pump: if this be the case, and the air within the pump be removed by the piston, the outward pressure of the atmosphere being no longer balanced, the water will rise in the pump. But when the liquid column has attained such a height that its weight balances the weight of the atmosphere, beyond this the column cannot

rise. From the experiment made by the gardeners, it is therefore to be inferred that a column of water 32 feet high exactly balances the weight of the atmosphere.

8. *Experiment of Torricelli.*—But if this be the case, when we take a liquid *heavier than water*, the height to which it can be lifted ought to be *less* than the height to which water is raised. Mercury, for example, is about 13 times heavier than water, granting then that a column of water 32 feet high is sustained by the atmospheric pressure, the column of mercury sustained ought to be only the thirteenth part of 32 feet, or in round numbers, 30 inches in height. Here then the experiment was suggested, which has made the name of its author famous. Torricelli took a tube *t*, fig. 13, more than 30 inches in length, open at one end, but closed at the other. Filling it with mercury, he stopped its open end by his thumb, and inverted it in a vessel *v* containing a quantity of the liquid metal. Judge of his satisfaction when he saw the liquid descend until the surface of the column within the tube was 30 inches above the surface without and remain stationary in this position; thus fulfilling, in the most complete manner, the conclusion at which he had arrived.

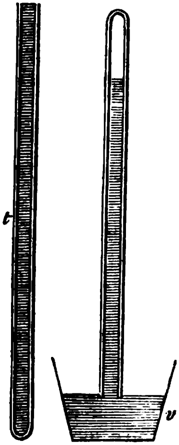

Fig. 13.

9. I would here direct your attention to the manner in which thoughtful reflection and experiment go hand in hand with a true natural philosopher, as Torricelli proved himself to be. If the former be not the prompter and guide of the latter, we wander blindly amid our experiments, and amass facts to little purpose. The opponents of Torricelli—for we must remember that he and his great master had nearly the whole world opposed to them—furnish us with an instructive example of the influence of prejudice upon the human mind. Sooner than accept the simple explanation of Torricelli, that the

column of mercury was supported by the atmosphere. a distinguished Abbé in those days affirmed that it was suspended by invisible threads! Natural Philosophy does not demand of its followers any unsteadiness of character, or unstable shifting from one opinion to another; but it requires that the love of truth shall be so predominant, that whenever truth appears, no personal feelings of our own shall be strong enough to prevent us from accepting it.

LESSON V.

CHANGE OF ATMOSPHERIC PRESSURE—THE BAROMETER.

1. *Decrease of Atmospheric Pressure with the Height.* —Following the Torricellian experiment to its consequences, we should infer that the column supported by the atmosphere in its higher regions ought to be less than that supported near the earth's surface; for as we ascend, the weight of the atmosphere above us diminishes. Pascal was the first to test the truth of this deduction. He took with him a Torricellian tube to the summit of a lofty mountain in France: he found, as he ascended, that the height of the column of mercury became gradually less; and that it rose again as he descended. This result has been abundantly confirmed by subsequent experimenters. De Luc, in a balloon ascent, found the height of the mercurial column to be only 12 inches, his elevation at the time being estimated at 20,000 feet. As is easy to conceive, the mercurial column may be, and indeed has been, actually converted into a means of determining elevations.

We have already described the methods by which the specific gravities of liquids are determined. A new method presents itself to us here, namely, that of weighing the liquid against the atmosphere. Supposing the pressure of the latter to be constant, the heights of the columns supported would be evidently inversely proportional to the specific gravities of the liquids.

2. Two cubic inches of mercury weigh 1 lb., and nce a column of the metal, with a square inch for its

base, and 30 inches in height, would weigh 15 lbs. Thus it is that we infer the pressure of the atmosphere to be 15 lbs. on each square inch of the earth's surface.

3. Arrangements were soon made to read off the height of the mercurial column with greater precision than was deemed necessary on the first experiments. The instrument had a scale attached to it near the summit of the column, and it was quickly observed that the surface of the mercury did not always stand at the same point of the scale. Within certain limits the height of the column varied, thus proving that the atmospheric pressure varied also. In its improved form, the instrument was called a *barometer*.

4. In the reading off of a barometer, the thing to be determined is the difference of level between the mercurial surface without the tube and that within it. It is evident that when the mercury sinks or rises, *both* of these surfaces change their level: now it is a matter of great convenience to be able to bring the surface of the mercury outside to the level of a fixed point, from which the barometer-tube is graduated. To effect this, the vessel *v*, fig. 14, containing the mercury, is furnished with a moveable bottom, which can be raised or lowered by means of the screw *s*. A pointed index *i*, of ivory or steel, is caused to depend from the upper portion of the vessel, and before reading off the instrument, the level of the mercury is so adjusted, that the point of the index barely touches the surface. The numbers on the scale denote the heights *above this point*, and consequently furnish us immediately with the difference of level between the two surfaces.

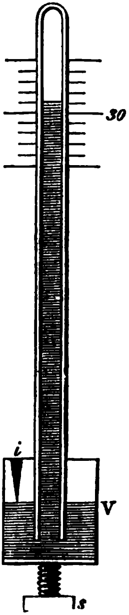

Fig. 14.

In the ordinary wheel-barometer, the fluctuations of the barometric column are transferred to an index which moves like the hand of a clock over the face of a dial. The arrangement will be understood from fig. 15. The glass tube, instead of being immersed in a vessel of mercury, is bent upwards, and the atmospheric pressure on the surface G, sustains the column within the tube. When the atmospheric pressure diminishes, the column falls, and the surface at G becomes elevated. On this surface swims a small adjusted float, from which a string passes over the pulley *p*: when the float is lifted, the weight *w* descends, and draws the pulley round: when the float sinks, the motion of the index is in the opposite direction. It is plain that if the index be long enough, a very small change in the level of the surface at G will produce a very sensible motion of the index.

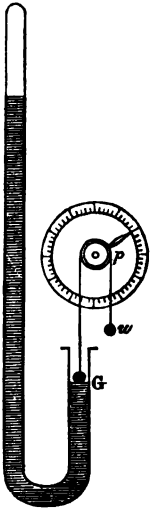

Fig. 15.

5. *How the Barometer may predict Rain.*—The barometer has received the name of the weather-glass; and in the hands of a skilful observer it may indeed be of great value in assisting him to make a close guess at the weather to be expected. Let us examine how this is possible. It is a fact, which we shall have occasion to refer to in our article upon heat, that when air is warmed it swells, and thus becomes specifically lighter. As a consequence of this, the atmosphere in our polar regions is *denser* than at the equator, and when the direction of the wind is from the north or north-east, the superior density of the moving air causes the barometric column to stand high. When, on the contrary, the wind blows from the south or south-west, the moving air conveyed to us from the equatorial regions is comparatively warm and light, and the lightness is accompanied by a corresponding depression of the barometric column. But you may here urge, that this does not explain why the barometer predicts *rain*,

for the direction of the wind has alone been spoken of. Both, however, are connected. It is a well-known fact that the higher the temperature of the air, the greater is the quantity of water which it can preserve in the form of vapour. Hence, if a mass of air, saturated with vapour, be transported from a colder place to a warmer one, the vapour remains uncondensed; but if it be moved from a warmer place to a colder one, condensation takes place, and a portion of the vapour is precipitated as water. Conceive, then, a current of air coming from the south or south-west: it approaches us laden with the vapours which it has contracted in passing over the ocean; but, inasmuch as it moves towards colder regions, this vapour is continually precipitated; and hence it is that the south-west wind brings us such plentiful showers. The wind from the north, on the contrary, has its moisture already precipitated to a great extent, and what it still holds, inasmuch as the air moves from colder to warmer regions, is preserved in the state of vapour: hence it is that the north and north-east winds are usually dry; and thus the barometer justifies, in some measure, its right to the popular name of weather-glass.

6. *How the Barometer may predict a Storm.*—But the barometric column has sometimes been observed to fall suddenly before a storm. Otto von Guerike, whom we shall have occasion to allude to again, predicted, in 1660, from the sudden fall of a barometer during a calm, that a storm must be raging somewhere: two hours afterwards the gale burst upon his own neighbourhood. On the 2nd of August, 1837, the harbour-master of Porto-Rico warned the seamen in the haven that a storm was to be expected, as the barometer had fallen 18 lines in a few hours. The warning was vain: the storm arrived, and of the 33 ships which the harbour contained not one escaped. At St. Bartholmew, 250 houses were destroyed, and at St. Thomas the hurricane carried a 24-pounder cannon along with it. Numerous other instances of a similar nature have been observed.

7. We will now proceed to consider how it is possible that the barometer can foreshow storms in this way.

From the most accurate observations it has been deduced that storms consist of bodies of air rotating round a centre. The little eddies that we observe upon the street, on a dusty day, are examples, on a small scale, of what we mean. Here it will be noticed that the particles of dust are carried round and round, and that, along with this motion of rotation, there is a motion of *translation*, as it is called, of the entire whirling mass from one place to another. In the case of great storms these two motions are also combined; the air whirls with great violence round a centre, while, at the same time, the centre itself is continually carried forward. Imagine a rotating cylinder of air thus impelled: the base of the cylinder, being in contact with the earth, encounters friction and other obstructions, is retarded, and hence the cylinder *leans forward*. The upper portion of the cylinder may, therefore, be over a place long before the bottom has reached it; the storm may be active above, while all is calm below. How then is the pressure of the air influenced by one of these atmospheric whirlpools? Owing to its swift rotation, the air is driven out from the centre on all sides, so that in the neighbourhood of the centre the space is partly *emptied* of air, and consequently cannot support a high barometric column. At the centre itself the depression is a maximum. Reflecting upon these facts, there is no difficulty in conceiving how the barometer may be affected long before the storm has reached it, and thus serve as a valuable warning to those who are able to interpret its indications.

LESSON VI.

THE RELATION BETWEEN THE VOLUME AND THE PRESSURE OF ELASTIC FLUIDS.

1. *Law of Mariotte.*—Having learned that air is compressible, our next step is to determine the exact relation between the amount of the compression and the force which produces it. This is done by means of the apparatus sketched in fig. 16. A B C is a bent tube glass, open at A, and furnished at C with a good

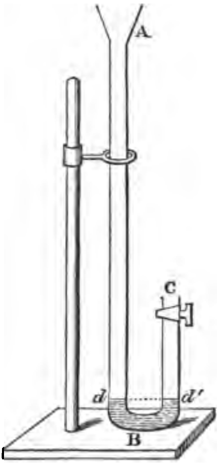

Fig. 16.

stop-cock. When the cock is open, let a quantity of mercury be poured into A, sufficient to close the bent portion of the tube at B, and to rise to the level of $d\,d'$, half an inch or an inch above the bent portion. Let the cock C be now closed: we have then a quantity of air enclosed in the space above the mercury surface d', and this is the air which we will submit to compression. Let mercury be poured in at A: as the column in A B heightens, the surface d' will be observed to ascend gradually, the air above it being squeezed into a smaller space by the pressure of the mercury. When the volume of air has been squeezed into exactly half its bulk, let the pouring in at A cease. Let the difference of level of the mercury in both arms of the tube be now ascertained: it will be found that this difference is about 30 inches. If A B be long enough, mercury can be poured in at A until the air in B C has been squeezed into one-third of its original volume; we should then find the difference of level in both arms of the tube to be 60 inches. To reduce the air to one-fourth of its volume, a column of 90 inches would be requisite, and so on. But how is it that the increase goes on by additions of 30 inches? Let us consider this state of the air in the tube B C *before* the cock at B was closed. It is evident that it then bore the pressure of the atmosphere above it, which, as already explained, is equal to that of 30 inches of mercury. When the tube A B is filled to a height of 30 inches above the level in B C, it is plain that two atmospheres, as they are called, are pressing on the air in B C. When the height of the pressing column is 60 inches, three atmospheres press upon the air; when 90 inches, a pressure of four atmospheres is exerted, and so on. Now, the experiment shows us that by doubling the pressure we reduce the volume of air to one-half, by trebling the pressure we reduce it to one-third, by increasing the pressure four times we diminish the volume four times; and hence we arrive at the important law—a law first discovered by the celebrated Robert Boyle, and rediscovered by Mariotte, whose name it usually bears—that *the volume of a gas is inversely proportional to the pressure under which it exists.*

2. For a long time it was considered that this law was perfectly true for all gases; but it is now known that this is not in strictness the case. When compressed in the manner we have described, some gases are finally reduced to the liquid condition. By cold and pressure, Mr. Faraday has liquified numbers of them. And it is found that those gases which are most easily liquifiable, or which, in other words, are nearest to their points of condensation at ordinary temperatures, exhibit very sensible deviations from the law of Mariotte. Carbonic acid and sulphurous acid are examples of gases of this class; while other gases, amongst which are the constituents of our atmosphere, have resisted all attempts hitherto made to liquify them. With these the law of Mariotte is true to a far greater extent than with the others.

3. To imprint the important principle above established upon the mind, it would be useful to work a few examples in which the law is applied. Want of space prevents us from giving more than one here.

Example 1.—Assuming the law of Mariotte to be true for all pressures, and that water is incompressible; at what depth below the surface of the sea would a bubble of air have the same density as the surrounding water, supposing the weight of the water to be 840 times that of the air at the surface, and that a column of 32 feet of water exercises a pressure of one atmosphere?

What is required here is to know what pressure will reduce a volume of air to $\frac{1}{840}$th part of the bulk it possesses at the surface of the sea, where the pressure upon it is one atmosphere. According to the law of Mariotte, a pressure of 840 atmospheres would accomplish this; and, hence, a depth of 32 feet of water being equal to one atmosphere, it might be thought that we have only to multiply 840 by 32 to find the depth sought. But it must be remembered that the air at the surface already bears the pressure of an atmosphere of air, and to these 839 atmospheres of *water pressure* must be added to make up the 840. Hence, multiplying 839 by 32, we obtain 26,848 feet as the depth sought.

Below this depth, if the above conditions continued to hold, the air would be *heavier* than the water, and would therefore *sink* instead of rise. It must not, however, be forgotten, that the case here supposed is an imaginary one, for water is not incompressible, and it is certain that long before the pressure referred to has been attained, the law of Mariotte ceases to be true.

4. *Further Effects of Atmospheric Pressure.*—In the barometer we see a column of mercury prevented by the pressure of the atmosphere from flowing out of the tube which contains it. If the top of the tube were perforated so as to permit the air to enter, the mercurial column would immediately sink. Such a perforation is made in the lid of a teapot, and if the lid fit tightly, you will observe that the water flows, or ceases to flow, according as the vent-hole is opened or closed. In water-glasses for birds, the liquid within the glass is sustained by the atmospheric pressure; the bird drinks from the bowl *a* (fig. 17), and finally the water within the bowl sinks, until a small bubble of air enters by the tube *b*. and ascends to the summit of the glass; here, by its elastic force, it presses the liquid downwards, and again partially fills the bowl *a*. In this way the process is continued until the whole of the water has been used. The pneumatic ink-bottle is made upon the same principle as the bird-glass: the bowl into which the pen dips is supplied in the same manner as that from which the bird drinks. Many lamps are so constructed that the oil is gradually supplied to the

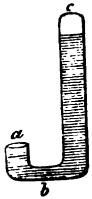

Fig. 17.

wick in the same manner as the water is supplied to the bird, or the ink to the pen.

5. In speaking of the weight of air, we referred to the case of a flask from which the air had been removed: we will now describe how this removal may be accomplished. A sketch of the exhausting syringe is given in fig. 18. C is a cylinder on which the solid piston P moves air-tight; *c* is a cock by means of which the external atmosphere may be admitted to, or shut off from, the space underneath the piston; *d* is a tube furnished with a thread at its lower extremity, on which the vessel to be exhausted, F, is sewed; *e* is a cock by means of which a communication may be established at pleasure between the flask and the cylinder C. The vessel being screwed on, let the cock *e* be opened, and *c* closed. When the piston P is raised, a portion of the air passes from F through *e*, and diffuses itself in the space below the piston. After the piston has reached its highest limit, let *e* be closed and *c* opened; in forcing P down, the air beneath it will escape through *c* into the atmosphere. Closing *c* and opening *e* again, the same process is repeated; at each successive ascent of the piston, a portion of the air is taken from F, and if the pumping continue long enough, it is evident that we can exhaust F almost completely.

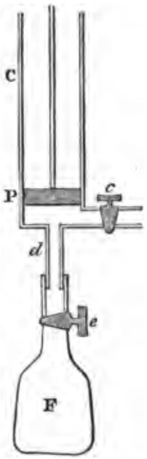

Fig. 18.

We might modify the exhausting syringe by doing away with the tube *e*, and making an aperture through the solid piston, to be closed by a valve opening upwards, as in the case of the common pump.

6. In the *air-pump* the exhaustion is hastened by making use of two cylinders, instead of one, the pistons of both being worked by a single winch. The instrument is shown in fig. 19. C C′ are the two cylinders in

which work the pistons P and P′, furnished with valves which open upwards. The pistons are raised by means of

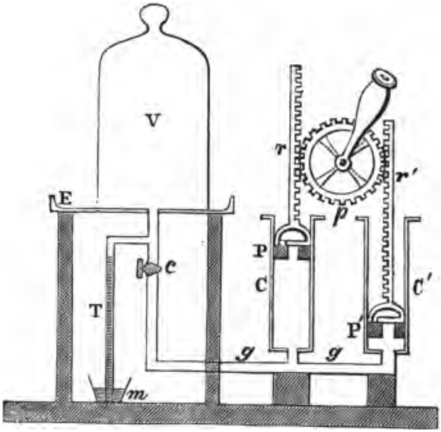

Fig. 19.

two racks *r r′*, and a pinion *p*. A tube *g* connects the cylinders with the vessel V, called a receiver, from which the air is to be exhausted. The edge of V is smeared with lard, to make the junction between it and the plate E air-tight. E is pierced at its centre with an aperture which communicates with the passage *g*. C is a cock which is opened when the receiver is exhausting, and closed when it is required to preserve the exhausted vessel from communicating with the atmosphere. A glass tube T, dipping into a cup of mercury, is usually connected with the passage leading to the receiver: according as this vessel is exhausted, the mercury is forced up in the tube T, and from the height at which it stands we infer the exact amount of exhaustion.

7. *Experiments with the Air-pump.*—If a closed bladder, half filled with air, be placed within the receiver V, as the latter becomes exhausted the air within the bladder swells, and finally quite distends the bladder. A shrivelled apple, under the same circumstances, becomes plump and fresh-looking through the expansion

of the gases within it. When the air is again admitted to v, through a cock provided for this purpose, the bladder collapses, and the apple becomes shrivelled once more. The real substance of wood is heavier than water, and the wood floats, on account of the air within its pores. When a piece of wood, swimming on water, is placed under the receiver, the air escapes on exhaustion from the pores of the wood, the latter consequently becomes heavier, and finally sinks like a brick.

8. *Magdeburg Hemispheres.*—But the most celebrated air-pump experiment is that made by its inventor, Otto von Guericke, burgomaster of Magdeburg, in northern Germany. The apparatus he used consisted of two hollow hemispheres of metal, fig. 20. The edges of the hemispheres are fitted accurately to each other, and before the experiment are smeared with lard to make their junction more perfect. From the lower hemisphere a tube issues, which can be screwed into the aperture in the centre of the air-pump plate, and thus the sphere, composed of these two halves, may be exhausted. This being accomplished, the cock *c* closed, and a suitable handle screwed on at *h*, it will be found that two of the strongest boys, each pulling at a handle, will not be able to force the hemispheres asunder; and if they were large enough, the strength of two horses might be exerted for the same purpose in vain. With such force does the external atmosphere squeeze the exhausted hemispheres together! On opening the cock *c*, so as to admit the air, the hemispheres separate without difficulty. The hemispheres with which this celebrated experiment was first made, and which the united strength of six horses was unable to force asunder, are still preserved in the city of Berlin.—JOHN TYNDALL.

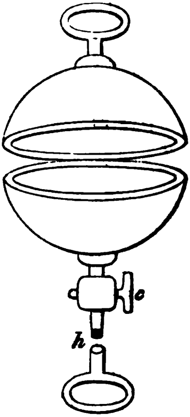

Fig. 20.

Astronomy.

BY ROBERT MAIN.

LESSON I.

WONDERS OF TELESCOPIC ASTRONOMY.

“ The heavens shall praise thy wonders, O Lord!”

1. WHATEVER may be the wonders of the starry heavens when viewed by the unassisted eye, these wonders are infinitely multiplied when the telescope is used to extend our vision. Even of the objects which are visible by the eye, such as the bright planets and stars, many wonderful properties are discovered by it which could not have been even surmised before. Of this we have a remarkable instance at the epoch of the discovery of the telescope. Against the Copernican theory, as contended for by the illustrious discoverer, it was objected that if the earth and all the planets revolved round the sun, then Venus, being an inferior planet, would exhibit phases like the moon. To this he replied, that it was probable such was actually the case, and the first glimpse of her through the newly-invented telescope confirmed the soundness of his views. We look back with much complacency at the dark gropings after truth, and the manifest errors committed by the celebrated men of past time, though one of the chief uses of such knowledge is to teach us humility by showing us the extreme liability of the mind of man to receive erroneous impressions and to argue on them badly, and that such tendency does not belong to one age in particular but to human nature.

2. The telescope has been to astronomy what the steam-engine has been to the arts; it has armed the astronomer with means for securing the utmost accuracy in the determination of the places of those bodies which were already known, and for extending indefinitely his researches into regions formerly supposed to be infinitely distant from us. On the other hand, it

has removed erroneous impressions concerning the solar and sidereal systems, and given just notions of the smallness of the former compared with the system of the universe. The stars, whose relations in space were not at all known previously to the discovery of the telescope, have been, by the successive degrees of precision attained by astronomers, removed as it were farther and farther from us, the accuracy of the observations enabling them to assert that no parallactic effect existed during the annual circuit of the earth that could be attributed to a finite distance of the stars. But at length optical skill and consummate observing skill combined, enabled the illustrious Bessel to resolve even this difficult problem, and to calculate in units of the radius of the earth's orbit the distance of one fixed star.

3. But greater wonders still remain behind. Let us, during an imaginary visit to an observatory, look into a moderately-good telescope—one, for instance, of which the object-glass is about 5 inches in diameter. On first looking into the field of view, the observer, if inexperienced, will see nothing distinctly; but, on examining a little more attentively, he will become conscious of the existence of a little patch of faint light: this is called a *nebula*, from its resemblance to a small white cloud. No stars are visible in it; but it appears of tolerably uniform brightness, a diffused mass of vaporous light, something, in fact, like an illuminated mass of fog. But let us now pay a visit to Birr Castle, the seat of Lord Rosse, near Parsonstown, in Ireland; and, if we are fortunate enough to induce his lordship to allow us to look at this same nebula, as exhibited on a favourable night in his immense reflecting telescope, what a different vision will be presented us! The uniform nebulous mass will now be seen, partially at least, resolved into innumerable minute stars, lying as thick as gold-dust in the field of the telescope, and forbidding all attempt at numeration. The form of the nebula is a beautiful spiral, with its convolutions as regular as those of a shell, and exhibiting a complexity of structure which the most profound astronomer of the present day can

only admire without daring to speculate upon. We are looking then not at a single body—not on a single world like our own sun (for the stars are in all probability suns shining with their own light)—but upon millions of bodies of the same kind, yet so incalculably distant that the angular space occupied by the whole system, as seen from the earth, is not above two or three minutes. The system, in fact, consists of as many stars as we see in a winter's night, is totally distinct from the sidereal cluster in which we are placed, and is at such a distance that we dare not hazard a conjecture concerning it.

We might in the same way hint at the wonders which are revealed, when the sun, the moon, and the planets are minutely inspected through a similar instrument; but it is better to take the subjects in their proper order, and to show in due gradation from how small beginnings such great results have been developed.

4. The telescope, as you are probably aware, was invented by Galileo at the very commencement of the seventeenth century. The actual amount of his claims to the first discovery is not quite agreed upon by historians, since his attention was drawn to the subject by the report that such an instrument had been invented in Holland. However, it is quite certain that his telescope was completed without having seen the Dutch instrument (if such actually existed), and probably without any hint derived from that source. It usually happens that every great discovery has more than one claimant; the state of the arts and the advance in intellectual cultivation determine the direction of the thoughts of the great men of the age, and the actual discovery is made by some fortunate individual who has by a little preceded his fellows in the race of intelligence.

5. Before we can properly understand what is to be expected from the powers of the telescope, we ought to be acquainted in some degree at least with its construction. In its simplest state it consists of two glasses, put together in a tube, of which the larger one, directed towards the object to be viewed, is called the *object-glass*, its province being to converge the rays of light

proceeding from a point of the object to a point called the *focus;* and the smaller one, nearest the eye, is called the *eye-piece* or *eye-glass*, its province being to render the rays proceeding from the image formed at the focus of the object-glass again parallel and fit for producing distinct vision on entering the eye.

6. The principle of the telescope depends upon a property of light called refraction, by which a ray of light is bent on its passage out of one medium into another,—for instance, out of air into water, or out of water into air; out of air into glass, or out of glass into air, &c.; and by this other property that the rays always travel in straight lines, and that an object is seen always in the direction in which the rays enter the eye. If, for example, a coin be placed at the bottom of a basin, and we retire to such a distance that it is just hid by the intervening side, then, by pouring in water (a medium denser than that of air), it will again come into view, having apparently risen, showing that the ray, after leaving the surface of the basin, in its progress towards our eye, is bent or *refracted* downwards, or farther away from the *normal* or perpendicular to that point of the surface. Now the water is denser than the air (these being the *media* in this case through which the light is passing), hence, in passing from a denser to a rarer medium, the ray is bent *farther* from the perpendicular to the surface separating the two media; and conversely, in passing from a rarer to a denser medium, it will be bent *towards* the perpendicular or normal. If we call the angle made by the ray with the normal, in passing out of air, the *angle of incidence*, and the angle formed with the normal, after passing into water, the *angle of refraction,* we may enunciate this as the law of refraction, that, in the passage from a rarer to a denser medium, the *angle of incidence is greater than the angle of refraction.* A most important connexion exists between these two angles, known by the name of the Snellian law of refraction, namely, that *the sine of the angle of incidence is for the same media in a constant ratio to the sine of the angle of refraction.* This proposition, taken in connexion with the properties

of the spherical surfaces of the glasses, or *lenses*, used in refracting telescopes, constitutes, when developed, the whole of their theory.

7. The surfaces of the lenses employed are segments of different spheres, and it is by the combination of different curvatures of the lenses with different kinds of glass, and by the choice of the distances at which they are placed from each other, that all the improvements in modern telescopes, admitting of the use of very large object-glasses, are due.

The following engraving gives the principal forms of the lenses ordinarily employed :—

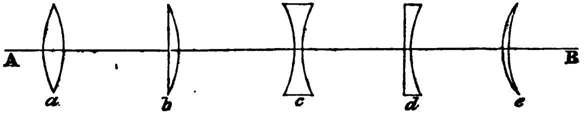

Fig. 1.

In which *a* is called a *double convex lens*, *b*, a *convexo-plane*, *c*, a *double concave*, *d*, a *plano-concave*, and *e*, a *meniscus*. Sections through the centres of the lenses are supposed to be represented ; and the line A B, which, in the case of lenses having two spherical surfaces, joins the centres of the surfaces, and in the other cases, passes through the centre of the one surface, and is perpendicular to the other, is called the axis of the lens.

8. Let us now see what will be the effect on a beam of light proceeding from an object so distant that all the rays, from every part of it, may be considered parallel, after its passage respectively through a convex and a concave lens.

Let A B be a double convex lens, C and C′ the centres of its spherical surfaces, and D E a ray of light parallel to the axis C C′, incident upon the first surface of the lens at E. It will be then bent nearer to the normal C′ E, into the direction E F, where it will arrive at the second surface. It will now pass out of glass into the air again, and will be bent farther away from the normal C F into the direction F G, where it will cross the axis, the bending being in each case towards the axis. If the lens be thin, and the curvatures small, every other parallel ray will cross the axis very near to the point G, which is called the principal focus of the lens, and denotes the image of a point of an object at an infinite distance, lying in the direction C′ C produced. Rays coming from other points of the object, not lying in the line C′ C produced, would fall on the lens obliquely, and would form an image either above or below G; and thus would an image of the whole object be formed. This image will plainly be inverted, since the rays proceeding from a point of the image above the line C C′ will, after crossing the lens, form an image below C C′, and *vice versâ*.

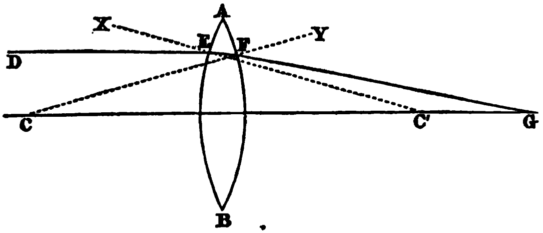

Fig. 2.

Since, however, each point of the image is formed by rays converging towards that point, and afterwards diverging, they require to be again rendered parallel, and this is effected by means of another glass or lens, called the eye-piece, placed at a distance from the image equal to its focal length. A telescope thus constructed is called the *astronomical telescope*, from its being generally used for the purposes of astronomy.

9. A telescope made, however, according to the principles now explained, would be a very bad one; and the image produced, instead of being distinct, would be tinged with all the colours of the rainbow, and would present only a confused resemblance to the object. This arises from another property of light called *dispersion*. Every beam of white light is composed of beams of light of the most brilliant colours, and whenever it is *refracted*, by being made to pass through a medium of different density, these colours are rendered visible.

Thus, if an ordinary prism be held in the sun-light, a *spectrum*, as it is called, brilliantly coloured with the tints of the rainbow, may be thrown upon the opposite wall. The several colours, as defined by Newton, are *red*, *orange*, *yellow*, *green*, *blue*, *indigo*, and *violet*,—the red occupying one end of the spectrum, and the violet the other, these being respectively the least and the most refrangible rays.

10. Now, it will readily be seen, that every lens acts as a prism, by refracting the rays of light, and, therefore, the images, formed by means of such lenses, will be coloured. To correct this fault, or to render the telescope *achromatic*, as it is called, a combination of lenses is employed. It was discovered by Dollond, the celebrated optician, that different kinds of glass have different dispersive powers; so that, by properly combining two single object-glasses, the one made of crown glass, and the other of flint glass, the rays could be made to pass through them, so as to produce a nearly colourless image. Such a compound object-glass is called an *achromatic object-glass*, and consists of a convex lens of crown glass, and a concave lens of flint glass. In the same way, by means of a combination of lenses, an *achromatic eye-piece* is produced, for the purpose of transmitting the image colourless to the eye. Of these eye-pieces, two sorts, called the *Huygenian* or *negative*, and the *positive*, and each consisting of a combination of two lenses, are used in connexion with the astronomical telescope. The negative eye-piece is not adapted for the application of the *micrometer*, or apparatus usually employed for measuring small angles, but is well adapted for *viewing* the heavenly bodies. But for all ordinary purposes of an observatory, the positive eye-piece is employed.

LESSON II.

MOUNTING TELESCOPES.

"I will fetch my knowledge from afar, and will ascribe righteousness to my Maker."

1. After having obtained a good telescope, the next point to be attended to is the mounting of it. This is a

point of great importance, for, in the use of high powers, it is necessary to be able to direct the telescope accurately in the direction of the object, and then to keep the object steadily in the field of view while under examination. Now, we know that all the objects in the heavens are carried by the diurnal motion in circles parallel to each other, and perpendicular to the polar axis, and, therefore, if we would comfortably observe any object, our telescope must have just such a mounting as will enable us to turn it round so as to follow the object at pleasure. In fact, the telescope produced to the heavens must sweep out a conical surface, of which our eye is the apex or vertex, and whose base is the diurnal circle described by the stars. We should evidently attain this object, if we could fix the telescope by the middle of its tube to an axis placed parallel to the earth's axis, and revolving freely, and if we were also to allow the telescope to revolve freely in the plane of the axis; for, having once found a star in the field of view, we could, by fixing the telescope relatively to the axis, and turning the axis round, follow it in its diurnal course.

2. A telescope with such a mounting is called an *equatorial instrument*, or a *parallactic instrument.* Divided circles are attached to it, the one perpendicular to the axis of revolution, or *polar axis,* called the *hour circle ;* and the other in the plane of the polar axis, or parallel to it, called the *declination circle.* The hour circle serves to measure the star's distance from the meridian; and the declination circle serves to measure the distance from the pole or from the equator. By means of the hour angle and the sidereal time observed by the clock, the right ascension of objects can be found, as well as their declination by the reading of the declination circle.

It is still a troublesome operation, when observing a faint or difficult object, to give such a delicate and uniform motion to the telescope as shall cause the stars to remain fixed in the field of view. To obviate this difficulty, *clock-work* is usually attached to all large equatorials, so regulated as to carry the instrument round with a uniform motion at the same rate as the stars.

3. We have hitherto treated only of *refracting telescopes*, or of such as are constructed on the principle of the convergence and divergence of the rays of light in passing through lenses of glass; but there is still a very important class of telescopes, called *reflecting telescopes*, in which a reflecting metallic mirror is used, instead of an object-glass.

Newton assumed, rather too hastily, that, for all kinds of glass, the whole dispersion (coloured or *chromatic* dispersion) is proportional to the whole refraction of the rays, and, therefore, that the defect arising from want of *achromatism*, that is, the confusion of colours in the images formed by refracting telescopes, did not admit of correction by any combination of glasses. He, therefore, turned his attention to reflecting telescopes, and invented the telescope which bears his name, that is, the Newtonian telescope.

4. The reader will readily understand that rays of light, either parallel or proceeding from a point, and falling on a well-polished speculum, whose surface forms a small portion of a sphere, will be made to converge towards another point, and that thus an image of an object will be formed, in a similar way to that described in the case of refracting telescopes. This image can be then viewed by means of eye-pieces, similar to those already described. In the case of the Newtonian telescope, the rays, while converging, are received upon a small plane reflector, inclined at an angle 45° in the tube, and are then made to pass through the glasses of an eye-piece placed properly to receive them, in the side of the tube. An objection to this kind of telescope is that, since light is lost at each reflexion (no reflecting surface being perfectly smooth), the use of two mirrors is prejudicial to the brightness of the image. In Sir W. Herschel's construction, the large object-mirror is a little inclined to the axis of the tube, and the rays, after forming an image, are received immediately, without a second reflexion, upon an eye-piece placed at the end of the tube, near its

edge. The position of the observer's head does not, therefore, interfere with the rays in their passage from the object into the tube. In Lord Rosse's large telescope, the second mirror is used for the sake of convenience.

5. The largest and most celebrated refracting telescopes at present existing, are those at Pulkowa, near St. Petersburg, in Russia, and at Cambridge, near Boston, in the United States of America. Each of these magnificent instruments has a clear aperture of the object-glass, amounting to about 15 inches, and a focal length of 22½ feet: as they were both made by the same artists, Messrs. Merz and Mahler, of Munich, they are mounted in a similar manner. This mounting is, of course, that which has been described as *equatorial* or *parallactic*, but with a peculiarity common to foreign instruments. In English equatorial instruments the polar axis terminates in pivots, one of which is above and the others beneath the telescope; and the telescope, with its declination circle, revolves in the plane of the polar axis, on an axis called the declination axis, which is supported by the polar frame connecting the ends of the polar axis. On the contrary, in the foreign mounting, or Frauenhofer mounting, as it is generally called, the telescope revolves on one side or the other of the polar axis, which, therefore, does not require a length proportional to the length of the telescope, and greater strength and firmness are thus secured. There are, however, several inconveniences attending it, of which one is the necessity of reversing the instrument, or putting the telescope on the other side of the pier on which the instrument is supported, when the object under scrutiny arrives, by the diurnal motion, on the meridian.

6. Of reflecting telescopes, the most celebrated is that of Lord Rosse, at Parsonstown, in Ireland; and we doubt much whether there are many individuals of the United Kingdom who have not heard of its fame. It has been explained that the most important part of such an instrument is the object-mirror or speculum, which corresponds

to the object-glass of refracting telescopes. The construction of very large telescopes, whether refracting or reflecting, is attended with very great trouble: in the former case, through the difficulty in procuring a piece of glass of the requisite size pure enough, or of sufficiently uniform substance, to let the rays of light pass properly through it at every part of the surface; and in the second case, by the very great difficulty attendant on the casting of a quantity of metal sufficient for making specula of large diameters, and the extreme caution necessary in the processes gone through for insuring a good surface, which will receive and retain a high and uniform polish.

7. The mirrors of Lord Rosse's telescope are 6 feet in diameter, and of 53 feet focal length, and each of them weighs nearly four tons. It was only after a long and painful series of experiments, with a combination of different metals, that the proper alloy was at length discovered by his Lordship, which gave the greatest hardness and ductility combined. The works necessary for the casting and polishing of these enormous specula and for properly mounting them, so that they should not bend under their own weight in different positions, were on a vast scale, requiring the application of steam power, and the labour of a great many men for a long period. It would have been exceedingly difficult, and not attended with any adequate advantage, to attempt to give to this enormous telescope an equatorial mounting, admitting of unlimited motion on each side of the meridian, and this therefore has not been attempted. Instead of doing this, it moves chiefly in the plane of the meridian, but has a motion of several degrees on each side of it, sufficient for continuing the examination of any interesting object for the requisite length of time.

8. It will be proper to mention another reflecting telescope, because of the important discoveries which have been made with it, and to which we shall have occasion to refer. The telescope in question is that of Mr. Lassell, a merchant of Liverpool, erected at his residen
at Stanfield near that town. The object-mirror of

telescope is 9 inches, and it was planned, cast, polished, and mounted by its proprietor, who has himself made many valuable discoveries with it, and has shown himself to be equally skilful as an observer and a mechanist, and to have united in himself all the qualities of a great astronomer.

Another telescope (a refractor of 7 inches aperture) has been used with great effect, namely, that belonging to the Rev. W. R. Dawes, at Wateringbury, near Maidstone, and to this gentleman's discoveries also there will be frequent occasion to refer.

9. Having acquired a distinct notion of the construction of astronomical telescopes, and of the method of mounting them equatorially, so as to render the use of them easy and effective, the next consideration is their application for the extension of our knowledge of the peculiarities of the heavenly bodies. The eye-pieces are generally screwed into a tube, which can be pulled out farther from the object-glass, or pushed in towards it, so as to bring it into focus; that is, to render the image of the object under examination, which is formed at the focus of the object-glass, distinctly visible by the eye after the passage of the rays through the eye-piece.

10. If the object viewed be a planet, the edges of the disk ought to be smooth and distinct when the telescope is in focus, and, if the object be a star, it ought to be round and well defined. Owing to the effects of irradiation, the images of the large stars will not be reduced to points, but will present the appearance of disks. These disks are not real, but *spurious*, and arise from the want of exact convergence of all the rays which form the image into an exact point. Those telescopes are therefore best which give the smallest and neatest images of a large star. The disks of planets are also subject to the effects of irradiation, and appear larger than they really are, especially those which are very bright, such as Venus. Finally, to try whether the object-glass of a telescope is in good adjustment, push in or draw out the eye-tube, so as to put the telescope decidedly out of focus, and then look at a star of the first or second magnitude. The image will then have the

appearance of a luminous ring, with a point in the centre. If this ring is complete, and of equal brightness in every part, the object-glass is rightly adjusted with respect to the tube, and the whole pencil of light passes through the eye-piece; but if the ring appear broken, the object-glass is tilted in the tube, and must be readjusted.

11. Close double stars, the distances of whose components are not above one or two seconds of space, are good tests of the *defining power* of large telescopes, and very faint stars are the proper tests of their *space-penetrating power*. If the object-glass be of an inferior description, the two stars composing the double star will appear blurred into one confused image, and very faint stars usually seen in good glasses of the same diameter will not be visible.

The chief of the celestial objects subjected to scrutiny by the telescope, are—

1st. The sun, the moon, and the planets.

2nd. The comets.

3rd. The fixed stars and nebulæ.

These classes we will take in their order.

LESSON III.

TELESCOPIC APPEARANCE OF SUN AND MOON.

"God made two great lights, the greater light to rule by day and the lesser light to rule by night."

1. The Sun.—For viewing the sun, directly, the eye must be protected by a coloured glass. Such glasses are either fastened separately (for different degrees of obscuration) into caps which screw on to the eye-piece, or are arranged in frames which slides across it. But an easier and pleasanter way of viewing the sun is to project the image upon a screen carried by the telescope, and the image will be still more striking if the dome or apartment in which the telescope is placed be previously darkened. Mr. Dawes has improved upon the method of viewing the sun directly, by inserting a perforated slide in the plane of the image formed by the object-glass: the perforations are so minute as to allow only the

rays proceeding from a very small portion of the solar disk to pass, so that this part can be examined independently of the rest of the disk, and without the indistinctness arising from the intense glare of the whole solar surface.

2. The first remarkable phenomenon which we are called upon to observe on the surface of the sun is that of the spots or *maculæ*. These are exceedingly variable, both in their frequency and size, being very plentiful and very large at some seasons, and very rare at others. They are generally of intense blackness towards the centre, and are surrounded or bounded by a ring or *penumbra* of much less obscurity. They are very irregular in figure, and some have been observed occupying several minutes of space, and preventing an appreciable quantity of light and heat from reaching the earth. If the eye be directed towards one of these spots on its first appearance at the eastern border of the sun (the apparent western border in an inverting telescope), it will appear like a very minute dot, and its motion, if it be followed, will be very slow. The next day it will have advanced towards the centre of the sun, and will appear larger, till at the end of about six days, it will be very near to the centre, where its rate of progress and its magnitude will be each at a maximum. It will advance in like manner towards the western border of the sun, becoming very much diminished in size, and moving very slowly, and will at length vanish there. If its path be mapped down from day to day, it will be found to be generally an elliptic or oval curve, except at the equinoxes in March and September, when the spots describe straight lines.

3. Now these facts, when properly considered, prove, first, that the spots belong to the sun's body, and are not bodies revolving round him, and, secondly, that the sun is a spherical body, having a motion of revolution from west to east, or according to the order of the signs of the zodiac; for, first, they are observed to enter at the eastern edge of the disk, and to vanish at the extreme western border, moving very slowly, and being very much *foreshortened* at these points, while their reatest velocity and greatest apparent size are attained

together near the centre of the disk. If then they belong to the surface of the sun, and are fixed to it, their apparent motion of rotation from east to west, proves that the sun has a real motion of rotation from west to east, and the axis round which he revolves is perpendicular to the apparent path of the spots. If through the axis of revolution, a plane be supposed to be drawn at right angles to it, this plane is called the *sun's equator*, and the points, in the sphere of the heavens, of intersection of this plane with the ecliptic are called the *nodes* of the equator. By calculations based on observations of the spots, the longitude of the ascending node of the sun's equator is about 80°, and its inclination to the ecliptic is about 7°; and finally, the time of the sun's rotation is about 25¼ days.

4. Near the edges of the disk, and generally in connexion with the spots, are observed undulating streaks or lines brighter than the general surface of the sun, and suggesting the idea of ridges or wave-like protuberances above the surface. These are called *faculæ;* and, though their origin is still obscure, yet their connexion with the spots and with the general disturbance to which the spots owe their origin, is sufficiently proved: Mr. Dawes had the good fortune to watch one of the faculæ to the very border of the disk, and to witness as a fact the suspected protuberance beyond the surface. He also observed the rotation of a very large spot, in January 1852, which gives an awful idea of the magnitude of the disturbances in the solar atmosphere, if we accept the usual theory, that the spots are openings in the gaseous or fiery envelope surrounding the sun, produced by storms in his atmosphere, similar to those which occur upon the earth's surface, and revealing, for a short time, the dark body beneath.

The accompanying drawings (fig. 3, p. 338) of some of these solar spots will give an accurate idea of their appearance in general.

5. The body which we are looking on, namely the sun, is of stupendous magnitude, as becomes, and is necessary for, the centre of the planetary system; but to convince the reader of this, we must assume a fact which will be

proved in a subsequent chapter—namely, his distance from the earth: this distance on the average (for it is slightly variable), is about 95,000,000 miles, while the assumed angular diameter of the sun, is about 32′. Many of our readers would, from these data, be able to prove that his real diameter is about 885,000 miles, and his real radius about 442,500 miles. Now the distance of the moon from the earth is about 240,000 miles. Hence if we were to suppose the centre of the sun to coincide with that of the earth, the surface would include the lunar orbit, and would extend almost as far beyond. This gives us a striking idea of the stupendous size of this wonderful body, the dispenser to us of light and heat, and the preserver of the uniformity of the motions of our own planet, the earth.

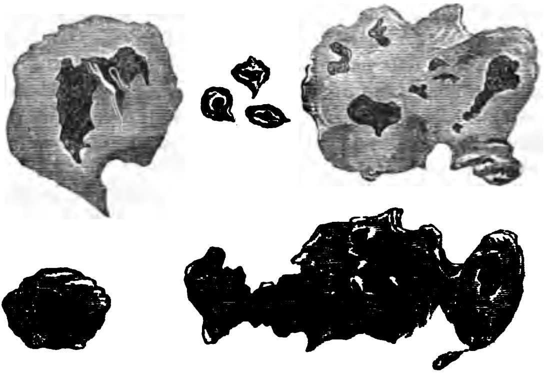

Fig. 3.

6. Some very interesting phenomena were elicited by the total solar eclipses of 1842 and 1851, which were exceedingly well observed at several places along the line of totality. One phenomenon of importance, was the appearance of a ring of faint light which encircled the black disk of the moon, but which is satisfactorily proved to belong to the sun. This ring consisted of diverging fans of light, diminishing in intensity as they proceeded farther from the centre, and had very much

the appearance of the halo or glory, usually depicted as surrounding the head of the Saviour. The second phenomenon was still more interesting, and consisted of protuberances or mountains of rose-coloured light, appearing at irregular intervals on the borders of the moon. These evidently belonged to the sun also, for they increased in height on the west side of the disk *from* which the moon was moving, and they decreased in height, and were some of them lost to view on the eastern side *towards* which she was moving. On one part of the disk, during the eclipse of 1851 there was seen a complete chain or *sierra* of these rose-coloured prominences, and a lurid glare was seen along the horizon, as the shadow swept across the country.

7. Very little is known of the real nature of these mysterious phenomena, and it is useless to speculate far beyond the inferences immediately deducible from the facts. The ring of faint light would suggest the idea of an atmosphere exterior to the luminous envelope of the sun, and the rose-coloured prominences might be masses of illuminated vapour suspended in it, very near to the surface of the envelope. Again, the sudden appearance of the solar spots, their irregular form, and their neighbourhood to the faculæ or undulating inequalities on the surface of the sun, suggest the idea of a partial removal of the envelope by means of the disturbances produced in an atmosphere or cloudy stratum between it and the body, which enables us to see the dark body of the sun within the envelope, in the centre of the opening forming the real spot, and the partially-illuminated clouds above it, which form the penumbra.

8. THE MOON.—The moon being so near to us (within 60 semi-diameters of the earth), it may be imagined that we should, by the use of the telescope, become much better acquainted with the physical peculiarities of her surface, than of any other heavenly body. The fact is really so, and maps have been made, almost rivalling in minuteness and accuracy those of the surface of the earth. Not only the situation, but the height of every mountain has been laid down on maps and raised models of the lunar surface; the radiating lines proceeding from

the craters of the volcanos, so numerously scattered over it, are traced to their terminations, and the general configuration of all their inequalities is faithfully given. One of the best known maps is that which was made by Dominic Cassini, and the names given to the principal points of the surface have been since retained. The apparently level portions are denoted by the name of *sea*, as *Mare Serenitatis*, *Mare Crisium*, *Mare Nubium*, *Mare Imbrium ;* and of these there are thirteen. The mountains have been named after astronomers and celebrated men, as *Tycho*, *Pythagoras*, *Macrobius*, *Newton*, *Huyghens*, &c.; and the latitudes and longitudes of these, referred to the moon's centre, are given, as well as their calculated altitudes in English feet.

9. The general appearance of the surface of the moon is that of a series of spent volcanos; large craters surrounded with rugged mountainous walls, and frequently with a heaped-up mass of volcanic matter in the centre; long gullies " hatched over " with large blocks radiating from the centres of volcanic energy, and probably thrown out in the terrible eruptions which must at some period or other have taken place; a general aspect of sterility, unvaried by the appearance or traces of seas or rivers or vegetation: such is the general appearance presented to us. It is quite clear that water does not exist upon the surface, and as a natural consequence vegetation does likewise not exist; neither under such circumstances can there be any atmosphere, and this is corroborated by observations of stars occulted by the moon. Hence if the moon has inhabitants, they must be very differently constituted from those of our globe; and the impression conveyed is rather that we look at the wreck of a world burnt up by fiery agency, at some remote period, whatever might have been its use or destiny during its former existence, and now waiting for those changes to be wrought by the Almighty in his own good time, when it shall awake like our own globe from its chaotic state, and be covered like it with sea and land, woods and forests, valleys and mountains, and with every evidence of consummated wisdom and goodness.

10. The moon invariably presents towards the earth the same hemisphere, with the exception of a trifling irregularity called *libration*, by which sometimes a little more or a little less than the average of the eastern and western limbs is brought into view. Now, as she revolves round the earth, she would, if she had no revolution on her axis, bring successively every portion of her surface into view: since then as much of the surface as is brought into view by the revolution in her orbit, is carried out of view by her rotation on her axis, it is plain that the time of rotation must be equal to the time of a sidereal revolution, that is to a month.

11. The best time for watching the physical peculiarities of the surface of the moon is from the time of new moon to the end of the first quarter. Then the sun's light falls obliquely on the visible surface, and the boundary of the illuminated surface presents admirable views of the mountains and craters. The rocky sides of the craters are seen boldly projected, while the bottoms of them lie intensely black in shadow, and frequently an intensely-bright point in the centre reveals the existence of an elevation or mountainous heaving up of the crust at the bottom.

12. The science of *photography* promises to be of material service to astronomy, by enabling us to make exact copies of the appearances of the heavenly bodies, and especially of the moon, under different circumstances. Every one is familiar with photographic and daguerreotype likenesses of individuals, and with pictures of scenery and buildings, and with the minute accuracy with which the slightest peculiarities of costume or feature in a portrait, or of architectural style in a building, are represented. The goodness of the picture (supposing the apparatus to be perfect) depends upon the fixity of the object during the time necessary to fix the impression made by the action of the light on the paper or the silver plate, previously rendered extremely sensitive by being washed with certain chemical substances. A picture of the moon might therefore be made in a similar manner by projecting the image up

paper or a plate properly prepared and properly protected from the action of extraneous light, if the position of the image could be kept for a short time immoveable, relatively to the paper on which it is projected. Now this is done with tolerable accuracy by all equatorials provided with clockwork, where the mounting is sufficiently firm to prevent any sensible tremor from being communicated to the telescope, and already some good specimens of photographic pictures of the moon have been produced. One beautiful image of the moon in her first quarter, taken by the great refracting telescope of the observatory of Cambridge, near Boston, in the United States, was exhibited in June 1853, and since that time other specimens have been exhibited by Professor Phillips and Mr. De la Rue.

13. The great advantage of such pictures is that they not only delineate the geometrical positions of all the parts of the object with absolute truth, but that every separate part requiring examination will bear a high magnifying power, and may be scrutinized at leisure.

LESSON V.

TELESCOPIC VIEW OF THE PLANETS.

"Thou, even thou art Lord alone: thou hast made heaven, the heaven of heavens, with all their hosts."

1. THE PLANETS.—Next to the sun and moon, the most important objects to be examined with the telescope are the planets. These must be taken in their order of distance from the sun, which, for the present, we shall assume without proof. Modern discoveries have, during the present century, added wonderfully to the number of those known to exist. In the order of distance from the sun, their names are, MERCURY and VENUS (revolving in orbits interior to the earth); the EARTH and MARS; a group of small planets included within a small range of distances from the sun, of which thirty-six are already known; and finally JUPITER, SATURN, URANUS, and NEPTUNE.

2. MERCURY.—Of the surface of Mercury very little is known, since it is always so near to the sun as to

render any accurate examination of it impossible. His apparent diameter, corresponding to his distances from the earth at inferior and superior conjunctions, varies from 12″ to 5″, and this corresponds to a real diameter of about 3000 miles. The German astronomer, Schröter, at the beginning of the present century, thought he discovered mountainous irregularities on the surface, and, by observation of these, he assigned a time of revolution to the planet on its axis, about equal to that of the earth, that is to 24^h. Both the inclination of his orbit to the plane of the ecliptic, and its excentricity are large, so that the variations of heat and cold must be very great; and if the heat from the sun act on the surface in the same degree as it does on that of the earth, its mean intensity must, from its proximity to that body, be so great, that mercury would be constantly kept in a boiling state.

Heat, however, is so modified by the media through which it passes that, without a knowledge of the atmosphere which surrounds this planet, we can say nothing positively respecting the actual heat which it experiences.

Mercury, being an inferior planet, of course exhibits phases like those of the moon, which can be calculated from a knowledge of his situation relatively to the sun and the earth.

3. Venus.—The next planet, Venus, is well known to everybody, from the brilliancy with which, for long periods, she occasionally shines as one of the chief ornaments of the sky. Her very brightness, however, is a hindrance to any very accurate observations of her surface, since few telescopes are so well corrected for colour, or are made so achromatic, as not to exhibit a highly-coloured image, prejudicial to exact definition of the boundaries of her surface. Nevertheless Schröter, the astronomer mentioned above, by very attentive observation of her, was enabled to see some spots on her surface, which enabled him to deduce a time of revolution on her axis, rather less than that of the earth. Her variation of apparent magnitude, as seen from the earth, is much greater than that of Mercury, her diameter sometimes exceeding 1′, and sometimes not being greater than 10″

Her real diameter is nearly 8000 miles, or of about the same size as the earth.

Some traces of an atmosphere have been detected, and this may probably, by its density, protect the surface of the planet, and the inhabitants, if there are any, from the intense heat and glare of the sun's rays.

She of course exhibits phases, and is, when viewed with a telescope, a very beautiful miniature image of the moon.

4. If the planes of the orbits of Mercury and Venus coincided with the ecliptic, it is plain that every time either planet came to inferior conjunction, that is every time it came between the earth and the sun, it would be projected upon the sun's disk. On account of the inclinations of the orbits, this does not happen often; but when it does take place in the case of Venus, this phenomenon (called the *Transit of Venus*) is of extreme importance, and is observed with the greatest care at different stations selected on the earth's surface, for the determination of the distance of the earth from the sun, or the solar parallax. This phenomenon, which is analogous to the eclipses of the sun and moon, will be treated of specifically in the next book.

5. MARS.—Omitting, for obvious reasons, the consideration of the Earth, the next planet on which our telescope is to be employed is Mars. This planet is easily distinguishable with the naked eye, by the fiery redness of his colour; but with the telescope, many peculiarities of his surface are discernible, on account of the apparent magnitude of his surface when he is nearest to us. His orbit has considerable excentricity, and therefore at some oppositions he comes much nearer to us than he does at others; and such opportunities are diligently made use of by astronomers for measuring his physical peculiarities. At the last opposition he did not come near to us, and the labour of a minute examination would have been in a great measure thrown away.

His diameter is about 4000 miles, and, by measures very carefully made under favourable circumstances, shape appears to be slightly elliptical, the equatorial eding the polar diameter by about 1–50th part.

6. He is evidently surrounded by a very dense atmosphere, and the spots on his surface are so easily seen that a tolerable map might be made by collecting the pictures given by different observers. The poles are generally capped with white, indicating the existence of snow in large quantities, and the mottled appearance of the remainder of the surface would seem to denote the existence of continents and seas similar to those of our own globe. In fact, there is no planet whose appearance presents so many points of similarity to the earth ; and the time of revolution on his axis, as found by the rotation of the spots, is only a trifle greater. His orbit also is very slightly inclined to the ecliptic, and the inclination of his equator nearly the same as that of the earth ; so that his seasons must be very similar, and the length of his year being 687 days, or rather less than two of ours, the seasons are brought round with tolerable rapidity.

Mars being a superior planet never appears horned like Venus, but is always *gibbous* whenever he is not in opposition to or in conjunction with the sun. On account of his time of revolution being about two years, his oppositions occur after the same interval of time, and when he is in perihelion also at this time he approaches the nearest to the earth.

7. SMALL PLANETS.—The next planet visible to the naked eye is Jupiter ; but between this body and Mars lie a group of minute objects moving in planetary orbits, of which the telescope alone has revealed the existence.

The history of the original discovery of the first known of these bodies is curious, and shows the value of an empirical law, even though it may prove afterwards to have no foundation in fact. The distances from the sun, of the planets known at the beginning of the present century, were connected by a numerical law, which they obeyed with as much accuracy as could be expected. Thus, calling the distance of Mercury 4, that of Venus is $4+3=7$; that of the Earth is $4+3\times 2 = 10$; that of Mars is $4+3\times 2\times 2 = 16$; that of Jupiter is $4+3\times 2\times 2\times 2\times 2 = 4+3\times 2^4 = 52$; that of Saturn is $4+3\times 2^5 = 100$; and that of Uranus is $4+3\times 2 = 196$

It appeared, therefore, that between Mars and Jupiter there is a gap in the series, for the planet next to Mars ought to have had for its distance $4+3\times2^3$; whereas Jupiter, the next known planet, was at the distance $4+3\times2^2$.

8. This law was pointed out to astronomers by Bode, and he was the means of directing attention to the necessity for a search for the missing planet; it has been called *Bode's law*, though it was known to Lambert and others before his time. An association was in consequence formed for the purpose of organizing an extensive search for the stranger, and different portions of the heavens lying near the ecliptic were allotted to its members; but, before operations were commenced on any scale, the first of the group of new planets was discovered at Palermo by the celebrated Piazzi, on the night of January 1, 1801. Piazzi had been invited to become a member of the association, but, owing to the slowness of communication by the post, the letter had not reached him when his discovery was made.

9. The smallness and fragmentary appearance of this body, which was named *Ceres*, induced Olbers to suppose that it might be one of the fragments of a large planet, shattered to pieces by some extraordinary convulsion at a remote period of time, and he began a search for other pieces of it, many of which, it could not be doubted, would, if the supposition were true, be found revolving in elliptic orbits round the sun. The next of them, *Pallas*, was actually discovered by Olbers on March 28, 1802, at the time when he and others were engaged in the search for Ceres at its first reappearance after its discovery. Olbers continued his search, according to his favourite theory of a shattered planet, searching in the neighbourhood of the place where the orbits of Ceres and Pallas intersect each other, but for some years with little success; indeed, we may say that the empirical theory in this case retarded the discoveries of this great man, by restricting his search within too narrow limits. The next planet in order of discovery was *Juno*, seen for the first time by Harding, on September 1, 1804, and the

fourth was *Vesta*, the brightest of them all, discovered at length by Olbers on March 29, 1807. A great many years elapsed before any other planetary discovery was made, the next of this curious group, *Astræa*, being discovered by Mr. Hencke (not a professional astronomer) at Driessen on December 8, 1845. Since that time the progress of discovery, through the labours of Hind, De Gasparis, and others, has been so rapid that, at present, no fewer than 36 of them are known, and the probability becomes each year stronger that a very large number of them still remain to reward the efforts of future astronomers.

10. Many of these planets recently discovered are exceedingly minute, sometimes not exceeding in appearance stars of the 12th or 13th magnitude, and the actual size of these must be very small, probably not more than 40 or 50 miles in diameter. The inclinations of their orbits are not confined to the zodiacal limits, and the excentricities are much larger than those of any of the ancient planets except Mercury. Some of these give plain indications of being surrounded by an atmosphere of considerable density: and this is the more remarkable, because to become sensible it must extend proportionally beyond their surface to a considerably greater distance than is the case with any of the larger planets.

11. JUPITER.—This is the largest planet of the solar system, and, if we except Saturn, whose ring perhaps renders him an object of still superior interest, is by far the most magnificent in appearance. When viewed through the telescope his surface is seen to be not of uniform brightness, but striped with belts across the equatorial regions. These belts are evidently of the nature of clouds or vapour, or more properly of disturbances in the atmosphere surrounding the planet, since they change their appearance sensibly when viewed at different times. Spots on the surface remain, however, visible long enough for the determination of the time of revolution of the planet on his axis, and this has been found to be very nearly $9^h\ 50^m$.

12. This rapid revolution would induce us to suppose

that the shape of the planet was elliptical, in conformity with the theory that supposes all the bodies of the solar system to have been at one time in a fluid state, like metallic substances liquified by heat, and to have been rendered solid after they have had time to cool down by the radiation of their heat into the aërial spaces round them. They would then retain, when solid, the same shape which they had previously, and this would be flattened or *spheroidal;* that is, the equatorial diameter would be larger than the polar diameter by a quantity depending upon their velocity of rotation, and greater in proportion as the motion is quicker.

Thus, the Earth, which turns round in 24 hours, has an ellipticity equal to $\frac{1}{300}$, and Mars has an ellipticity equal to $\frac{1}{50}$ or $\frac{1}{60}$; while the sun and the moon, which revolve in periods not greatly differing from a month, have no measurable ellipticity.

The ellipticity of Jupiter is about $\frac{1}{17}$, as found by a great many determinations made at the Royal Observatory of Greenwich, and is very much greater than that of the earth, as we might have predicted from the velocity of rotation.

The angular diameter of this vast globe, at the distance of about 438,000,000 miles, is 40,″ and this corresponds to a real diameter of about 85,000 miles.

13. As we have had already more than one occasion to deduce the real diameter from the apparent, we may take this opportunity to explain the method by which this is effected.

If A B, fig. 4, represent the real diameter of Jupiter viewed from the earth E, and C be the centre of the

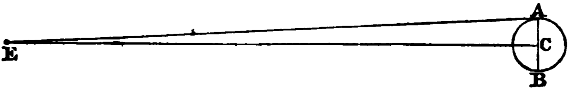

Fig. 4.

planet, then A C E is a right-angled triangle, and the angle A E C is the half of the angular-measured diameter as seen from E; hence A C is equal to E C multiplied by the tangent of 20″, or to 20 E C multiplied by the tangent of 1″. Now this latter quantity is equal to $\frac{1}{206270}$, hence, the distance E C being 438,000,00 miles, the semidiameter of the planet is $\frac{20\ 438000000}{206270}$ or 42,500 miles nearly. Whence the diameter of the planet is equal to 85,000 miles approximately. To estimate in some degree the size of this stupendous body, we must remember that the distance of the moon, which we are apt to regard as a distant body, is about 240,000 miles, or only three times the diameter of the planet.

14. Jupiter is attended by four *satellites*, or moons, and these add materially to the interest of the view obtained of him in the telescope. These satellites, being opaque bodies, revolving round him in nearly circular orbits, are occasionally eclipsed in the shadow of Jupiter; and since these eclipses must occur at sensibly the same instant of absolute time at every point of the earth's surface, they are useful in determining the longitudes of the places where they are simultaneously observed, if the *local* time (depending on the time of the sun's passage over the meridian of that place) be also obtained by observations of stars.

There is a curious and interesting fact connected with the motion of these satellites, which may be thus enunciated. "The mean longitude of the first satellite, added to twice that of the third, differs from three times the mean longitude of the second by 180°." This law leads to the conclusion, so remarkable as an illustration of the wisdom of the Creator, that all the satellites cannot be eclipsed at the same time.

The satellites are seen sometimes to pass across or to transit the disk of Jupiter; and this phenomenon is interesting, as proving the superior intensity of the light near the centre of the planet, since they are seen distinctly near the borders as bright spots, but are lost sight of on approaching the centre. They are also seen to pass behind the body, and are then said to be *occulted*.

The diameters of the satellites are about 2500, 2060, 3400, and 2900 miles respectively.

The accompanying picture will give some idea of the appearance of Jupiter and his satellites when seen through a good telescope.

LESSON V.

PLANETS—*continued.*

"By the word of the Lord were the heavens made, and all the host of them by the breath of his mouth."

1. **Saturn.**—The planet Saturn is of very nearly the same size as Jupiter, and is in some respects of superior interest; his diameter is very nearly 80,000 miles, and his measured ellipticity (far greater than that of any other planet) is one-ninth nearly. This determination, arrived at by the author of this portion of the work, agrees precisely with that of the astronomer Bessel, made at a preceding disappearance of the ring. The *ring*, or rather the assemblage of rings which surround the planet, forms the most interesting part of the Saturnian system, and has given rise to many interesting speculations. The fact of the existence of a bright ring was discovered almost immediately after the invention of the telescope; but the discoveries of modern times depend upon most refined and delicate observations made with very powerful instruments. Of these, the first is the great division, or dark space, near the boundary, which any good telescope will show with tolerable facility. It is a problem in itself sufficiently difficult to account for the stable equilibrium of a ring of solid matter revolving round the planet, but it becomes still more complicated when several uncon- ted rings revolve in this manner. It was formerly ected, and has since become more probable, that er division (exceedingly difficult to be seen) exists

between the primary division and the outer edge, and Mr. Dawes suspects that several other very minute divisions may exist, though they are too small to be distinctly seen. This excellent observer, to whom we are indebted for a great deal of valuable knowledge respecting the Saturnian system, saw, occasionally, that the intensity of light was not uniform on the surface of the ring, but that it appeared to be subject to sudden gradations of shade. The exterior portion of the inner bright ring, for about a fourth of its whole breadth, was very bright, but interior to this the gradations of brightness were clearly seen to be arranged in a series of narrow concentric bands, each of which was somewhat darker than the next exterior one. It will be proper to add in this place that many astronomers of eminence have never been able to convince themselves of the existence of the *outer* division, though the gradations of brightness are confirmed by the observations of Mr. Bond, of Cambridge Observatory, in America.

2. But the most remarkable discovery of the present century respecting the rings, is that of an inner ring, so very slightly reflective that its existence was scarcely suspected till it was discovered, almost simultaneously, in the year 1850, by Mr. Bond in America and by Mr. Dawes in England. This *dusky, or semi-reflective ring*, extends from the inner boundary of the inner bright ring, filling up nearly one-half of the supposed dark space between it and the body, and is now easily recognisable by any practised observer using a good telescope, though it still requires a sharp and well-practised eye to discern it. It is easily distinguishable also by the dark line which is projected upon the body of Saturn, and it is wonderful that so many years could have passed without its recognition. It has been satisfactorily ascertained, by more than one observer, that it is semi-transparent, and from this circumstance we may imagine that it can scarcely be a solid substance, though it would be idle without farther data to speculate much on its nature.

3. Saturn is now known to be attended by eight satel-

lites, whose mythological names are Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus; Mimas being nearest to the planet, and Iapetus farthest from it. Iapetus was discovered by Cassini in 1671; but Hyperion, the next in order of distance from the sun, was not discovered till the month of September 1848, when it was seen for the first time, almost simultaneously, by Mr. Bond and Mr. Lassell.

4. The distance of Saturn from the sun is about nine times that of the earth, and the disk of the sun would subtend therefrom to the inhabitants of this planet, if there are any, an angle of scarcely 4′, while the light and heat which are received from that luminary are scarcely one-eightieth of the light and heat received by the earth. To compensate for these disadvantages, they enjoy for part of their long years the splendid spectacle of the ring illuminated by the sun and spanning the firmament, and their eight moons help to relieve the gloom of their long winter. The glimpses which we catch of Almighty wisdom on these outskirts of the solar system are sufficient to enable us to rest satisfied that, if this vast globe under consideration is inhabited by beings created by God, he has also given to them organizations adapted to the place in creation assigned to them for their dwelling place.

The annexed drawing will give an idea of the appearance of Saturn and his rings when viewed through a good telescope.

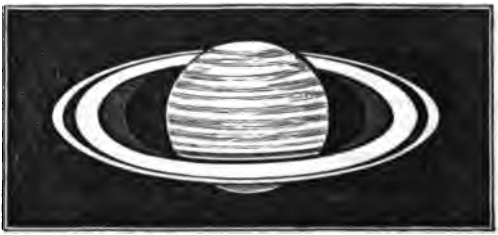

Fig. 5.

. Uranus.—This planet being at the immense dis-
e of 1,828,071,000 miles, or nineteen times the earth's

distance from the sun, does not present any remarkable physical peculiarities when viewed through a good telescope. The apparent angular diameter is about 4″, which corresponds to a real diameter of 35,000 miles; but it must be observed that the effects of irradiation are greater proportionally for small disks than for large ones, and this result must be looked upon only as a tolerably near approximation to the truth. There does not appear to be any appreciable ellipticity or deviation from a spherical shape in the planet, as deduced from the measures of two eminent astronomers.

6. The disk of the planet is so small that in a cursory sweep of the heavens it might be easily mistaken for a star; but an inspection of it by an experienced eye would soon prove it to be of a planetary nature, and in this way it was actually discovered by Sir W. Herschel in 1781, while engaged in a sweep of telescopic stars in the constellation Gemini, with his seven-foot reflecting telescope. His attention was immediately attracted to its planetary appearance; and the application of a higher power confirmed the discovery of a new *body* of the solar system. But so little expectation was there of the discovery of a new *planet*, that for some time he believed it to be a comet, notwithstanding the absence of all physical characteristics of a cometary nature.

On account of the smallness of the disk of Uranus, no belts or spots have ever been observed on his surface, and hence the time of his revolution on his axis is not known. From the undoubted smallness of his ellipticity, however, we may conjecture that his rotation is not so rapid as that of Jupiter or Saturn.

7. Uranus is attended by several satellites; but, on account of their faintness, only four at the present time are known with absolute certainty to exist, though from the observations of Sir W. Herschel it is presumed that there are others which have escaped the notice of modern observers. Two of these were observed, first by Sir W. Herschel, and reobserved by his son Sir

John Herschel, and their periods of revolution have been accurately ascertained.

In 1847 two new satellites, each inferior to the bright ones of Sir W. Herschel, were discovered by Mr. Lassell and Mr. Otto Struve; and it is suspected that a third was seen, but this latter has not been again identified. Mr. Lassell has since that time been able to follow up the observations of both these bodies, and, by comparison of his observations made in 1847, 1851, and 1852, has very satisfactorily determined the time of the revolution of each round the primary planet. Mr. Lassell has assigned to them the names *Ariel* and *Umbriel*, in their order of distance from Uranus. In conclusion, then, we may say, that if Sir W. Herschel's observations were correct, four more satellites, at least, remain to be discovered.

8. NEPTUNE.—The discovery of Neptune was not due to the telescope alone, but to the application of the highest analytical skill of two eminent mathematicians, to an almost-despaired-of problem. The problem may be thus enunciated, "Given the disturbing effect produced by one body of the solar system on another body; to find the position of the disturbing body?" We may illustrate this roughly by the effect produced by the moon on the tides. The elevation of the water above its average height is chiefly due to the action of this luminary in pulling the water immediately under her, or nearest to her, with greater force, and the water opposite or farthest from her with less force than it does the solid matter of the earth. The consequence is, that the surface of the water, instead of being spherical, is changed into an oval shape whose larger axis follows the moon in its diurnal revolution at a short interval. Now suppose that the moon was invisible, but that we knew the law of her action in producing the tides, we might then propose to ourselves the problem: "Given the heights of tides at various places on the earth's surface; to find the positions at various times with reference to the centre of the earth, or the orbit of, the body producing them?" This problem would, to say the least, be excessively difficult, and, perhaps in this

instance, impossible, but it conveys an apt illustration of the *inverse problem of perturbations*, as it is called.

9. Two astronomers, the one M. Le Verrier, at present director of the Observatory at Paris, and the other Mr. Adams of St. John's College, Cambridge, were engaged on this problem at the same time, without any knowledge of each other's proceedings, and almost at the same time, each produced an orbit of an *unknown planet exterior to the planet Uranus*, the existence of which would reconcile the discrepancies and anomalies in the motions of that body, which were becoming very puzzling to astronomers.

The first discovery of the disturbing planet was due to M. Le Verrier, who sent confidently a position of the presumed exterior planet to Dr. Galle, one of the astronomers at the observatory of Berlin, requesting that he would search for it. It was discovered almost as soon as the telescope was directed towards it, on the evening of September 23, 1846.

It is due to Mr. Adams to state, without entering into details, that the planet was twice observed at the observatory of Cambridge, in consequence of his researches, though without being recognized, before its discovery at Berlin.

10. Neptune has been necessarily an object of great interest to astronomers, and has been well scrutinized by the use of the most powerful telescopes; the chief result is the discovery of one satellite. The apparent diameter of this planet is about 2½″, and its form is generally considered to be elongated, and to afford presumptive evidence of its being attended by a ring, in the same manner as Saturn. Its real diameter is probably about 30,000 miles, and it revolves round the sun at the enormous distance of thirty times the earth's distance from that luminary. Hence on the surface of this planet, the sun's angular diameter would be about 1′, and the quantity of light and heat about 1-900th part of that received by the earth.

LESSON VI.

COMETS AND FIXED STARS.

"Look now toward heaven, and tell the stars if thou be able to number them."

1. Comets.—Comets visible with the naked eye visit us but rarely; but the telescope has revealed to us a great number of such bodies, whose existence we could not otherwise have suspected. They differ very much from each other in their physical appearance, as well as in the orbits which they describe round the sun. In general, when viewed through the telescope, there is observed a bright condensation of light of a circular form, with sometimes a star-like or planet-like point in the centre, called the *nucleus:* this is surrounded by a nebulous fringe or border, which, from a fanciful resemblance to a head of hair, is called the *coma*, and otherwise the *envelope;* and lastly, the envelope surrounding the head of the comet is frequently extended to a considerable length on both sides, and is called the *tail* or train. The matter of which comets are composed is known to be exceedingly attenuated, since the faintest stars are seen through the densest parts of them, though a fog near the earth's surface will extinguish the light of stars of the first magnitude. One comet actually passed very close to the planet Jupiter, without producing any derangement of the motions of the satellites, though it appears that so much disturbance was produced in its own motions that its orbit was totally changed, and it has never again visited the neighbourhood of the earth.

2. The orbits of comets may be divided into two classes chiefly, namely, those of which the excentricity of the orbit, though much larger than that of any of the planets, is so moderate, that they complete their revolutions in a few years, and those which revolve in exceedingly long ellipses, and require a very long and generally incalculable period of time to complete their revolutions.

3. The most celebrated of the comets of short period is that called *Encke's comet*, which completes

its revolutions in little more than three years. The theory of the motions of this comet has been attended to most laboriously for many years, by the great astronomer whose name it bears, and a very curious fact seems to result from his labours, namely, the existence in space of a very thin resisting medium. It is found that it performs each successive revolution in a shorter interval of time than the preceding; and if this be universally true, it receives an adequate explanation in the fact of a resisting medium which, though producing no perceptible difference in the time of revolutions of the planets in a finite period, yet may sensibly affect a light vaporous body like a comet. It will, however, require several more revolutions of the comet to put this important and curious fact beyond the reach of doubt.

Another remarkable comet of short period is *Biela's comet*, whose time of revolution is about 6¾ years. At its apparition in 1846, it appeared to be divided into two separate bodies visible together in the same field of the telescope. Both bodies were extensively observed, and Professor Plantamour of Geneva computed very rigorously the orbit described by each of the component parts of the comet. In a still more recent apparition, both comets were again seen.

4. Of comets of longer period, the most celebrated is *Halley's comet*, the return of which was first predicted by that illustrious geometer. According to his prediction, it appeared in the year 1759; and at its next apparition in 1835, it was most anxiously watched for, and most diligently observed. Its period is about 76 years, and its return, according to prediction, affords a most conclusive proof of the correctness of the assumed law of gravitation.

5. In 1843 appeared a very large comet, with a tail from 40° to 50° in length, seen principally in the southern hemisphere. At its perihelion passage, that is, when it approached nearest to the sun, it was so brilliant as to be seen at noon-day, and it must have approached very close indeed to the surface of that luminary.

Our readers will remember to have seen, in the autumn of the year 1853, a brilliant comet in the western sky, with a tail like a sword, pointing upwards, of several degrees in length. In the month of April 1854 also there was visible a comet of almost precisely similar appearance, which, as seen in a telescope, we have endeavoured to represent in the accompanying engraving (fig. 12), giving, however, the view not inverted, but as seen in the heavens.

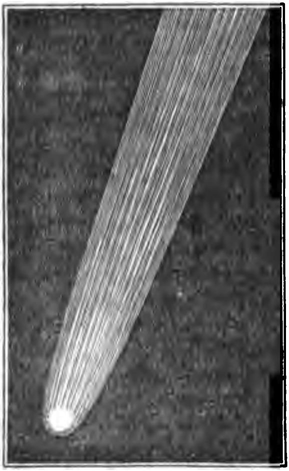

Fig. 12.

6. Fixed Stars.—All the bodies above treated of belong to the solar system, that is, they either revolve about that body immediately, or are satellites to others so revolving. The fixed stars, however, form a totally different class of objects, and require distinct notice before we close this chapter.

The bright planets (so called from their motion) are not readily distinguished from stars of the first magnitude, when viewed with the naked eye, except by the steadiness of their light; but, when the telescope is used, a marked difference is immediately perceptible. The planet becomes really magnified, and the peculiarities of its disk, even with respect to slight gradations of colour and minute characteristics of form, become visible. But no such difference is discernible in fixed stars; the best telescopes give the smallest apparent diameters to bright stars, and if the telescope were absolutely perfect, all the light of the star would be concentrated in a brilliant point. The disk of the star is *spurious* and not real; and the telescope merely helps us in assigning to it a position very much more distant than any of the bodies of the solar system.

7. But, it may be asked, how do we know that the stars are at such enormous, and, in most cases, incalculable distances as astronomers have assigned to them? Granting them to be so far off, that the angle subtended by the rays coming from the opposite borders of their disks is too small to be measurable by us, does it necessarily follow that their distances must be sensibly infinite? The mere test of a vanishing disk would not, indeed, be sufficient to prove this, if it were not attended by every other indication of remoteness. Of these indications, the first is implied by their name, *fixed stars.* This name is slightly incorrect, since we have reason to believe, from the accurate comparisons of the places of large numbers of stars observed at tolerably distant intervals, that most of them have motions capable of being measured; but these motions are so exceedingly small, in comparison with those of the planets, that, in contradistinction to them, they may without any impropriety be styled fixed. Now, since all the bodies which we see around us are in motion, it is highly improbable that the stars are *really* fixed; and, therefore, the exceeding smallness of their motions give us an idea of their vast distance.

8. On the contrary, when we have found a star with a comparatively large proper motion, there is a presumption (till the contrary be proved) that it is nearer to us than other stars. Such a star is 61 Cygni (thus designated by Flamsteed, the first astronomer at Greenwich), and we cannot set before the student a more instructive example. This star has been for many years known to have a great proper motion, amounting to about 5″ per year (a small quantity, taken absolutely, but very great when compared with the motions of other stars), and thus there was great antecedent probability that the distance of this star from the earth would prove to be measurable. But it had other claims to notice besides its proper motion. It is a double star, consisting of two very nearly equal stars, separated by an interval of about 15″, and (which is still more curious) these components revolve round each other;—in fact in 70 years they have described round each other an angle of 50°. They

are evidently connected with each other by the tie of gravity, or by such a power as causes the sun and planets to revolve round their common centre of gravity; only in this case we have the grand spectacle of one *sun* revolving round another *sun*, since both are bodies shining by their own light, and are therefore, in all human probability, bodies similar in magnitude and nature to our sun.

The astronomer Bessel undertook to find the distance of this *binary system* from the earth; and succeeded in doing so. The result which he arrived at has been confirmed by several other astronomers, and admits of no doubt. The distance then that he assigned to this star (the nearest be it remembered, to the solar system as far as is yet known) is more than 600,000 times the distance of the earth from the sun. By considerations also derived from the time of revolution of the component stars round each other, compared with the time of revolution of the planets round our sun, he found that the sum of their masses was equal to about one-third of the mass of the sun.

9. NEBULÆ.—A very remarkable class of objects, equally distant from us with the stars, are the nebulæ. As has been stated before, these appear, in an ordinary telescope, like small patches of faint light, but when viewed through Lord Rosse's telescope, they are generally found to consist of innumerable masses, or *congeries* of stars, scattered as thick as gold-dust in the field of the telescope. Many of those which have been already examined give evidence of a most wonderfully complicated structure, particularly those which are denominated *spiral* nebulæ. Of these, one of the most remarkable is No. 51, in Messier's Catalogue, which consists of a curious system of spiral lines, radiating with various degrees of brightness from a disk-like bright spot, and having, at the extremity of one of its curves, another spot, similar to the centre of divergence, which is probably the centre of a companion nebula.

10. What an exalted idea do the preceding revelations give us of the grandeur of the works of the Almighty, ıd of the vast, and to us illimitable scale, on which his

operations are carried on! We see but glimpses of his glory; painfully, and step by step, we have found access to the outer courts of his dwelling-place; our view is dim and imperfect, yet may we see enough of the majesty of Him, the all-powerful, all-wise, and all-merciful Being, who has made all these marvellous works, to cause us to exclaim with the pious Psalmist:—"Lord, when I consider the heavens the works of thy fingers; the moon and the stars which thou hast ordained, What is man, that thou art mindful of him: and the Son of Man, that thou visitest him."

Robert Main.

VOICE OF NATURE.

The spacious firmament on high,
With all the blue ethereal sky,
And spangled heavens, a shining frame,
Their great original proclaim:
Th' unwearied sun, from day to day,
Does his Creator's power display,
And publishes to every land
The work of an Almighty hand.

Soon as the evening shades prevail
The moon takes up the wond'rous tale,
And nightly to the list'ning earth
Repeats the story of her birth:
Whilst all the stars that round her burn,
And all the planets in their turn,
Confirm the tidings as they roll,
And spread the truth from pole to pole.

What, though in solemn silence all
Move round the dark terrestrial ball?
What though no real voice nor sound
Amid their radiant orbs be found?
In Reason's ear they all rejoice,
And utter forth a glorious voice,
For ever singing, as they shine,
The hand that made us is divine.

Addison.

LIFE OF CELLINI.

BY J. C. ROBINSON.

LESSON I.

1. THERE has perhaps never been a more striking instance of individual genius identifying itself, as it were, with entire branches of art or science than that of Benvenuto Cellini. Had this great artist lived in some remote age of antiquity, instead of during the period of the revival of art in the sixteenth century, he would, doubtless, now have appeared to us in the light of a fabulous impersonation; tradition would have gifted him with superhuman powers, and we should have accustomed ourselves to connect his name with his craft, using, in poetic language, either term indifferently. The great names of the world are indeed those which we thus involuntarily connect with great works—noble and enduring reward of excellence achieved.

2. Benvenuto Cellini was a Florentine artist born A.D. 1500; died 1570. By profession nominally a goldsmith, he was in reality a great ornamentist, sculptor, jeweller, engraver, musician—in short, equally excellent in whatever branch of art he chose to engage. This admirable versatility of talent, so rare at the present day, was by no means uncommon at the great epoch of the revival of arts and letters in Italy; and it may be worth our while to consider in what way powers so extraordinary were developed. There can be little doubt but that a long-continued preparatory study of the general principles of art was the chief cause: theory and practice being made to go hand in hand. Young students in those days were generally engaged to masters of eminence, just as at present apprentices are bound to handicraft trades; and with good reason, for it will be evident, on reflection, that excellence in art, avowedly very difficult to acquire, is even less likely to result from the unassisted endeavours of the student than proficiency in any mechanical trade, which must be presumed to demand far less skill and application.

3. Although the painters and sculptors of the sixteenth century believed in the efficacy of original genius, they

knew that genius alone, unguided and uncontrolled, would never lead to real proficiency, any more than natural cleverness, without practice and proper teaching, would, for instance, make a good carpenter or a good blacksmith. It was the custom for every artist of repute to receive into his studio or workshop a number of scholars, who, whilst devoting the greater part of their time to general study, were likewise allowed to see and to participate in their master's works. Drawing and modelling from the remains of antique sculpture, copying in various ways the great works of antecedent artists, the study of anatomy, and of the human figure from nature, and numerous other exercises, were carried on year after year, until, by the contemplation of the beautiful in nature, and familiarity with all the great models of style, the judgment of the pupils became gradually matured, whilst their manual powers were simultaneously developed.

4. It will be well now to turn our attention, for a brief space, to this remarkable period of the revival of art in the sixteenth century, designated the "Renaissance," or revival, by the French, and by the Italians called the "Cinque-cento," or *fifth century*. The admirable art of the ancient pagan world had dwindled down to the merest shadow of its former excellence many centuries before the period now alluded to; and during the "dark ages," as they are called, in which Christianity became gradually established, and the germs of modern civilization developed, the remembrance even of the ancient excellence was forgotten; the Church became the great patron of arts and letters. As the Christian religion relied on spiritual truths and inward feelings, rather than on that strange mingling of fanciful allegory and merely sensual love of the beautiful and perfect in external nature, which was the essence of ancient pagan creeds, Christian art resolved itself into an imperfect and mysterious striving to express, by symbols and types, facts and sentiments which it was really not within the province of art to embody. In this way, when an ingenious symbolical device was more esteemed than the most beautiful representation of nature, it was natural

that little care should be given to attain to truth and beauty in works of art. The technical processes of the arts, however, were never entirely lost; and as Christian temples and ceremonies became gradually more gorgeous and ornate, all the various methods and appliances formerly in use were again employed: the artists of these periods being most frequently monks, who, in the quiet seclusion of the cloister, carried on in peace and safety occupations, which the barbarous state of society rendered unprofitable, and scarcely possible even, to the ordinary layman. These monks, moreover, handed down the technical processes in written treatises and receipts one to another; and Christian art attained in its own sphere to great excellence, and, in fact, was most completely developed at the period of the birth of Cellini.

5. In Italy, as in ancient times, the chief excellence was displayed. Italy at that time was the richest and most civilized country of the world. Her commerce was with all lands, her traders being frequently nobles and princes. Things rich and rare from all climes were brought home by her ships; her merchants, as they were great and wealthy, were likewise enlightened, learning and good taste giving a grace even to their luxury. In Florence the celebrated Medici family were, if not the first, certainly the greatest patrons of art and learning since the great age of Rome. The earlier princes of that family assembled around them the greatest scholars and the most renowned artists of the age: their court was itself an academy. Soon the dry and puerile literature of the middle ages was replaced by the writings of the great authors of antiquity, manuscripts of whose precious works were sought for with the utmost eagerness; and in an incredibly short time the knowledge of the ancients, thus disinterred, worked a revolution in literature, and art was not slow to follow. On all hands the precious relics of antiquity, statues, medals, gems, were disinterred, enthusiastically admired, and copied with avidity. Thus a real revival of ancient t was brought about. Heathen gods and goddesses, nphs and satyrs, took the place of saints and

apostles, whilst scenes and subjects from holy writ were treated like profane histories. The Caduceus of Mercury again became the symbol of commerce; Minerva's owl, the cornucopia, the olive and the laurel, the lyre and the torch, again shadowed forth the idea of wisdom, plenty, peace and glory, poetry and the grave.

6. Our purpose being as much to throw light on the industrial or ornamental arts of this epoch, as to compile a biography of an individual, which, moreover, in the case of Cellini, has been done with the greatest spirit and fulness of detail by himself, it will be sufficient to relate the leading circumstances of his eventful career in as concise a manner as possible, referring the reader to his well-known autobiography for more complete information.

Cellini belonged to a family of artists; his grandfather was an architect, and his father, who exercised the same profession, was likewise an adept in carving in wood and ivory, and in the making of musical instruments, being at the same time passionately devoted to the practice of music. Benvenuto was early instructed by his father in this latter accomplishment; but he soon showed a more decided inclination for the arts of design, and was accordingly, at an early age, bound apprentice to the most celebrated goldsmith in Florence. He appears to have worked with more than one master before leaving his native city, which he was obliged to do whilst still very young, having been banished by the magistrates for taking part in an affray. On quitting Florence he visited many of the great cities of Italy, working at his profession in the shops of eminent goldsmiths, and assiduously studying the works of the greatest masters in painting and sculpture, particularly those of Michael Angelo and Leonardo da Vinci.

7. Having at last arrived at Rome, then, as since, the resort of artists from all parts of the world, he devoted himself to the study of the works of the ancients, which, as we have before remarked, were then beginning to be understood and appreciated. His time was chiefly occupied in making drawings of the numerous ancient monuments; and there can be little

doubt that he was one of the first and most enthusiastic collectors of antiques, for he informs us that it was his custom to lie in wait for the peasants from the country around Rome, in order to purchase from them the ancient medals, cameos, gems, &c., which they found whilst tilling the soil. From these acquisitions he derived a twofold profit, as they were, in themselves, the most admirable models for imitation, whilst his taste and knowledge enabled him to sell them again with great advantage to wealthy collectors.

8. It would be impossible here to describe a tithe even of the great works executed by Cellini, and, in most cases, commented on in his memoirs; we can but refer to some of the most important whilst dwelling on the main points and phases of his life. His earliest productions appear to have been articles of silver plate and personal ornaments, such as clasps and buckles. These were for the most part ornamented with exquisitely-designed figures and animals, scrolls, masks, and natural foliage, the details of which were conceived in the spirit of the antique.

9. We likewise find him, when about twenty-three years old, learning seal-engraving from a celebrated artist named Lautizio, of Perugia. Whilst profiting by the example of the famous goldsmith, Caradosso, of Milan, he became expert in the making of delicate ornaments in gold, such as the beautiful medals or brooches, which it was then the custom to wear in the hat, and which were usually enriched with figures and groups in high relief, exquisitely chased and enamelled. His works in these branches soon made him known to the Roman cardinals, from several of whom he received important commissions. Whilst thus engaged, however, he still found time to cultivate music, and with such success as to be admitted to perform before the Pope, who made him one of his court musicians.

10. About this period (A.D. 1527) occurred perhaps the most extraordinary event in Cellini's romantic and
turous career; and here it must be observed, that
h our concern is with the man as an artist, there
r and not less striking view to be taken of his

character and actions. Cellini was feverishly active for good or evil in all the usual transactions of life: his energies were not entirely absorbed in his art—war, politics, pleasure, intrigue, in these he was one of the restless spirits of the age. Thus we find him playing a conspicuous part at the period of the sacking of Rome by the soldiers of the Duke of Bourbon; and Cellini avers that the musket-shot, which slew that famous leader, whilst scaling the walls, was fired by his hand. Cellini was then engaged in the defence of the Castle of St. Angelo, the citadel of Rome, in which the Pope and his courtiers had taken refuge. But our limits will not allow us to dwell upon these marvellous adventures, though they form a most striking chapter of his autobiography. One of his most notable works, undertaken shortly after this time for Pope Clement VII., was the button or clasp used to fasten the Pope's pontifical robe. It was customary to display the utmost richness of workmanship in this particular ornament, which, though we have called it a button, for want of a better term, was made of considerable size, generally from six to nine inches in diameter. The work in question was of gold, set with the most costly jewels, and it will not be digressing from our subject to take this occasion of briefly describing the processes employed in its production.

11. In his Treatise on Goldsmiths' Work, &c., Cellini has given us an exact account of the mode of executing this work; but it will be impossible here to follow him in his elaborate technical description: the various figures, however, some of which were in such high relief as to be in parts completely detached from the background or field of the medallion, were entirely wrought, by the process of hammering, out of a single flat plate of gold, the utmost care being taken to keep the metal of uniform thickness in every part. This was accomplished by striking or embossing it, sometimes from the back and sometimes from the front; whilst, in the parts detached from the ground, great skill and ingenuity were exercised in cutting out the gold so as to separate them from the

flat plate, and likewise in soldering, repairing, and inserting pieces where required. When by these means the proper degree of relief was obtained, the back of the work, which exhibited corresponding hollows and depressions, was filled with a composition of pitch and wax, requisite to give it sufficient strength and consistency to admit of the final process of chiselling or chasing up the surface of the piece. All the more minute and beautiful details and finishing of the parts being elaborated with little chisels, graving-tools, files, burnishers, &c. Lastly, the ornamental border was enriched with enamels, another remarkable process, which consists in painting or enriching the gold ornaments with colours fusible by heat into beautiful gem-like glasses. This work was the means of bringing the artist into universal repute, and was allowed by all to be an incomparable masterpiece. Cellini was next employed in making dies for the papal money; and the numerous coins and medals executed by him were at an early period treasured up as works of the highest art.

LESSON II.

LIFE OF CELLINI—*continued.*

1. OUR artist's fame had now travelled to other countries; he had become known to the two great potentates of the age: the Emperor Charles V. and Francis I. King of France. To the former of these monarchs he had occasion to present, on the part of the Pope, a manuscript enclosed in a magnificent cover of gold of his own work; whilst the latter, who had become possessed of a beautiful jewelled medallion, likewise executed by him, soon became desirous of attracting so great an artist to his own court. Francis I. was a most enlightened and munificent patron of art, and had already secured the services of many of the most celebrated Italian masters, who were chiefly engaged in the decoration of his magnificent palace at Fontainebleau, where they ultimately founded a celebrated school of art. Cellini accepted the offers held out to him by the king, and went to France; but, in an evil hour, disgusted at

some fancied neglect, he returned to Italy again, without having undertaken anything.

2. In the meantime a new pope had succeeded to the chair of St. Peter, and Cellini, having incurred the displeasure of one of his favourite relations, was thrown into prison on a vague charge of having stolen certain gold and jewels, during the period of the siege of the Castle of St. Angelo, when he was employed by Pope Clement to melt down the pontifical plate and regalia. The circumstances of his imprisonment, as related by himself, are in the highest degree romantic, indeed more like fiction than reality; yet there is no reason to doubt the substantial truth of his narrative. After making his escape in an almost miraculous manner, and being a second time consigned to his dungeon, he was ultimately released by the intercession of the king, Francis I., who, being informed of his captivity, and regretting the loss of his services, was most anxious to induce him to return to France.

3. Cellini's second residence in France was the most brilliant period of his career. This time the king treated him with truly regal liberality, and indeed soon loaded him with commissions of the highest importance, rendering it necessary for him to employ numerous assistants, some of whom were his own Italian scholars, and others selected from amongst the ablest French goldsmiths, who were glad to work under so great a master. Our space will only allow us to enumerate the principal works executed by Cellini in France. The first commission he received was indeed a magnificent one, on so grand a scale even that it was only in part carried out. This was for twelve silver statues of the gods and goddesses, as large as life, to be placed round the royal dining-table as supporters for candelabra. Models of these were soon made in clay, and one of them, representing Jupiter seated on his throne, was not only executed in silver, but likewise repeated in bronze.

4. The production of works of this great size in silver was attended with extraordinary difficulty, insomuch that a previous attempt by native artists h

been attended with complete and ludicrous failure. The process employed by Cellini was that of hammering, the trunk, head, limbs, &c., of each figure being made separately, from silver plates embossed in the manner already described, and finally soldered together, which operation required the utmost skill to accomplish in figures of large size, owing to the difficulty of handling or turning them in the furnace. Cellini, notwithstanding his unceasing occupations, seems now to have lived in a princely manner, his munificent patron having assigned him a liberal allowance, besides paying handsomely for all his productions. Francis, moreover, placed at his disposal a royal castle, adjoining the walls of Paris, for his residence and workshops, and ultimately ennobled him and gave him an estate. These favours, however, were not conferred without exciting the envy and opposition of a crowd of interested hangers-on of the court, as well natives as his own countrymen, so that he was soon involved in all sorts of contests and intrigues. Cellini now appears to have especially devoted himself to monumental sculpture in bronzé, in which, as we shall afterwards see, he was as successful as in his small and delicate works in the precious metals.

5. The great works in bronze, previously alluded to, were chiefly intended as architectural decorations for the palace of Fontainebleau; and amongst other undertakings we must specify the principal door and gate of the palace, and all its surrounding decorations, which were of the richest and most elaborate workmanship. It is uncertain, however, if this was entirely completed as originally designed. He likewise began a magnificent fountain, ornamented with a colossal statue of Mars, fifty-four feet high, which does not seem to have been carrièd further than the model in clay; for Cellini's restless disposition would not allow him to establish himself permanently in France, and we find him, at last, abandoning possessions, emoluments, and works in progress, and again returning to his native city, where he finally took up his abode.

6. On his return he took service with the reigning

Duke of Florence, who, although possessed with an hereditary love of art, was by no means such a noble patron as the French king, and for a long time Cellini had to battle with the whims and caprices of this prince and his consort, who persisted in employing him only on trivial undertakings. His great fame and success here also procured him the opposition of a host of rivals, whose malignity, it must be confessed, was sharpened by the arrogant conduct of Cellini himself. Amongst these rivals, Baccio Bandinello, an eminent sculptor, was his bitterest and most constant enemy. Bandinello was especially piqued at Cellini's success in sculpture, and lost no opportunity of decrying his productions in marble and bronze—the artist, since his return to Italy, having devoted himself more especially to works of fine art in these materials. Notwithstanding this opposition, Cellini at last succeeded in inducing the Grand Duke to give him a commission for a group in bronze, to be erected in the great square of Florence, in which already stood admirable works by Donatello, Michael Angelo, and Baccio Bandinello himself, who shortly before had executed a colossal statue of Hercules and Cacus in marble for this conspicuous locality.

7. The subject of Cellini's group, which is still to be seen, is Perseus holding forth the head of Medusa, and trampling under foot the headless trunk; it is fixed on a marble pedestal of the most exquisite workmanship, which is enriched with four smaller bronze figures, and a profusion of beautiful ornaments carved in the marble, and would alone suffice to stamp him as one of the greatest artists of any age. This group, indeed, at the period of its erection, was infinitely admired, being generally pronounced much superior to the work of his rival Bandinello. Owing to its great size, and the peculiar design and position of the figure of Perseus, the casting of the work offered many technical difficulties, in the overcoming of which Cellini manifested such fertility of resource and indomitable resolution, as to have given double lustre to his success. An admirable lesson indeed may be learned from the perusal

of the interesting account of the operation of casting the figure, as given in his Life. We have there a most forcible picture of genius and perseverance working together—of presence of mind, and the completest forethought manifested amidst an almost frantic energy of action.

8. Another celebrated work executed for the Duke was a marble figure of our Saviour on the Cross, of the size of life: this likewise procured him great applause. Increasing years indeed seem neither to have impaired the activity of his mind nor diminished the amount of his labour; and he appears to have continued to the last to work in almost every branch of his art with an ease and versatility which defied competition. Space will only allow us to briefly specify several other methods or species of work in which Cellini was known to have been an adept. Amongst these minor arts that of *niello-working* is not the least remarkable: this beautiful process, little used at present, consists in the ornamenting of silver by means of engraving, the incised lines made by the graving-tool being filled up or inlaid with a darker-coloured composition of silver, lead, and sulphur combined together. Analogous to this is the art of inlaying or incrusting one metal upon another, termed *Damascene work*, and which is most frequently applied to the decoration of arms and armour. *Filagree work* in gold and silver, a delicate process of forming trinkets, vases, caskets, &c., in fine wire. Die-sinking and the process of striking money, gilding, etching, &c. These various arts he is known to have constantly practised, whilst he was a most expert and accomplished jeweller, especially in all that concerns the setting of precious stones, so as to enhance by artificial means their natural colours and lustre.

9. Cellini ended his days in peace and prosperity in his native city of Florence, having attained to the age of seventy; and it is recorded that he was interred in the church of the Nunziata, with a grand funeral pomp, at which were present the Members of the Academy, and the Company of Sculptors, the populace eagerly struggling to get a sight of the body as

it lay in state. In bodily constitution Cellini was strong and robust, whilst he was endowed with a nervous energetic temperament, prompting him to unceasing activity; he was ardent and generous in his friendships, but irascible and quarrelsome to excess: his daily life was a continual romance, for his imagination constantly outran his judgment, and yet, in matters of art, this latter was most profound and intuitive. Inspired with a firm and lofty confidence in his own high powers, he never for a moment doubted of success in whatever he undertook; no difficulties appalled him, obstacles and rivalries alike gave way before his impetuous will: to conceive was to execute—there was no indecision in his character. He believed himself all-accomplished, and he made himself so; withal he was proud, overbearing, and revengeful, and not very truthful. Men's characters, however, are often made or marred by the good or evil tendencies of the age in which they live; and the age of Cellini, although brilliant, was wicked and corrupt, and his great faults, on which in this short account it was needless to dwell, were rather those of his country and the period than peculiar to the man.

J. C. Robinson.

Fine Arts.

LESSON I.

BEAUTY OF FORM IN NATURE.

BY DIGBY WYATT.

1. It has pleased the beneficent Designer of "the world and all that therein is," not only to surround man with the ever-varying and inexhaustible beauties of nature, and to endow him with the gift of sight to perceive her graces; but He has been pleased also to confer upon him a mind to understand and a hand to imitate them. These gifts are clearly talents committed to our charge, and to be accounted for by us. The same Power

"That gave us in this dark estate
To know the good from ill,"

conferred upon us also an unerring test to distinguish the beautiful from the mean or ugly. That test is the sensation of delight which invariably accompanies our recognition of beauty, moral or physical. Whenever the powers of the mind are concentrated upon any of the great external evidences of Omnipotence—upon "the heavens above, or on the earth beneath, or on the waters which are under the earth," it is impossible to refrain from pouring forth a tribute of silent but heartfelt admiration; and at such moments the Creator, as if to mark His approbation of the sacrifice, lulls, for a while, all memory of earthly pain or care, and pours peace and happiness into the soul. Thus it is that "a thing of beauty is a joy for ever." It is impossible to examine the smallest object upon which the skill of Divinity has been exercised—a shell, a flower, or an insect—without feeling a longing to know somewhat of the mysterious laws which make that individual specimen of design so perfect, and without experiencing a desire to emulate the marvellous powers of creation. The first sensation of the exercise of such powers we feel to be Godlike. Thus it is man naturally attempts, in his feeble way, to emulate the loftier faculties of Divinity; and thus "'tis to create, and in creating live a being more intense, that we endow with form our fancy." From such exertions springs all that is ideal or poetical in every art.

2. Whenever we attempt to penetrate the wondrous system that makes all nature one vast harmony, it is impossible to refrain from feeling that

> "God moves in a mysterious way
> His wonders to perform,"

and that it is, as yet, our portion only to see the full light of His majesty "as through a glass darkly." Enough, however, is still apparent to teach us that there are conditions of harmonious relation which pervade the most exquisite forms in Divine creation; and it is only while catching a faint reflection from their glories that we can hope to succeed, in the slightest degree, in throwing a veil of beauty over our omparatively insignificant productions.

3. We recognise an almost universal beauty throughout the works of nature by the exercise of some faculty, as intuitive as memory, and not less inexplicable when we essay to predicate concerning its ineffably mysterious constitution. It has been well observed by some metaphysical writers, that in the development of the intellectual powers, the first effort is to realize, the second to enjoy, and the third to reason. In accordance with this theory, the first and constant effort of every child is to feel, to see, to use its senses, and to verify the fact of its existence by ascertaining its physical relation to all by which it is surrounded. Its second and occasional effort is to eat, to drink, to smell, to show pain and pleasure, likes and dislikes, and to observe and treasure up such experiences as can affect its subsequent enjoyment. The third effort is to exercise the gift of thought, and to form conclusions by other processes than those of direct sensation. Now we, as respects our knowledge of Divine beauty, can be regarded only as very little children; and if we would improve upon our condition of ignorance, instinct leads us onwards through parallel states of progress. Let but the first effort of one totally uneducated in art be to see and to feel nature, to look upon her works with an observant eye, and he will almost instantly find himself led on by unerring sensations of delight to the second stage of advancement. In that stage he will enjoy, discriminate, select, store in his memory, and at length endeavour either to reproduce, or cause to be reproduced, those natural objects, contact with which has caused him the greatest direct satisfaction. No sooner does he arrive at the full development of his secondary condition, than he passes into the third. He begins to speculate upon the sensations he experiences, upon the phenomena of their recurrence, and on the means whereby he may be enabled, by his own descriptions or imitations of the original types, to convey to others the pleasure he himself derived from the contemplation of them—thus the ignorant may grow into the connoisseur, and thus the child into the artist.

4. A knowledge of the sequence of these natural phases of transition, points out the course by which, alone, special education in decorative art can be brought to a successful issue. Surround the pupil with every attainable example of general beauty of form, if he is to be a general artist or draughtsman; make him acquainted with all the antecedent productions in his specialty, if he is to be a special designer; show him only as much as possible of what is good, whether general or special; then his sense of enjoyment will teach him selection, and he will store his memory with the best. Practise his hand as you educate his senses, and the feeling of power will soon come upon him. Reason will assert its empire, and inquiry will be stimulated. Once roused, effort will succeed effort, and thus in time the pupil will grow into the master. As it is impossible to arrive at correct theories in science, except by the analysis of accumulated observations, firstly of things, secondly of properties, and thirdly of relations, so it is impossible to assume any general conclusions concerning Divine design without passing through the three stages of realization, enjoyment, and reflection.

5. When we take into consideration, on the one hand, the shortness of life and the limitation of the powers of man, and, on the other, the extent and illimitable divisibility of matter and its incessant changes in form and application, we cannot but feel conscious in how slight a degree the best disposed and most talented students of nature can have become acquainted with her innumerable phenomena, a thorough knowledge and enjoyment of which we have shown to be indispensable to any just general conclusions. It is only by the transmission from generation to generation of accumulating experience and deductions, that the very few points we are about to indicate have been assumed as universal recurrences in the external forms in which nature pours forth her bounteous gifts to man.

6. The first quality with which the observer must be struck is the infinite *variety* of form which pervades creation. On attempting to reason concerning it, he

perceives its dependence upon the functions which each object, and the component parts of each object, are ordained to fulfil; hence he at once recognises the fact, that form is in every case, if not dependent on, at least coincident with structural *fitness*. When the most complex flower is submitted to the test of a scientific botanical examination, no particles are found to be adventitious, all are concerned in fulfilling the appointed functions of vegetable physiology. As those functions vary with the growth of the plant, so in every case does its form, changing from tender bud to blooming flower, and from blooming flower to reproductive seed-pod, as each successive change of purpose progresses. Infinite *variety* and unerring *fitness* thus appear to govern all forms in nature.

7. While the former of these properties demonstrates her infinite power of complexity, the latter restrains the former, and binds all in beautiful *simplicity*. In every case ornament appears the offspring of necessity alone, and whenever structural necessity permits, the simplest lines consistent with the variety of uses of the object are in every case adopted. Thus, the principal forest trees, which spring erect and hardy from the ground, in their normal state, uninfluenced by special conditions of light or heat, shoot straight aloft, with boughs equally balanced on all sides, growing so symmetrically that a regular cone or oviform would, in most cases, precisely define their outline; and thus the climbing plants, from their first appearance, creep along the ground in weak and wayward lines, until they reach something stronger and more erect than themselves; to this they cling, and from it hang either vertically or in the most graceful festoons; to each its character of form as of purpose, to each the simplest line consistent with its appointed function and propriety of expression. From nature's delight in *simplicity*, man probably derived his earliest perception of geometrical figures. The term horizontal at once betrays the source from which our idea of such a line may have been derived. Upon the horizon, as a base, endless perpendiculars are erected in every plant that

pierces the soil at right angles to its tangent. A plain in nature furnishes the idea of a plane in geometry. Every variety of triangle is indicated by the outline of the snow-clad peaks of the loftiest mountains; every kind of cone by their substance. The thin clouds that sweep along the sky at sunset, hanging over the distant blue line of the ocean, form exquisite parallels; and where cut by the lines of trees and plants, suggest every variety of square and oblong, rhombus and parallelogram.

Where compactness is indispensable, the honey-yielding hexagons abound; and in her endless variety of crystals nature has furnished us with models of the most exquisite solids. In the rainbow we have her noblest arch; in the parabola at once one of her most graceful curves and most elegant formulæ of projection.

8. While a consideration of the quality of *fitness* binds us to *simplicity*, that of variety, as if in counterbalance, conducts us to a just recognition of the value of *contrast* throughout all the works of creation.

Nature, in working out her harmonies of contrast, abounds with optical corrections. The infinitely-gentle convexity of her water sky-line is precisely corrected into perfect apparent horizontality by contrast with any line at right angles to a tangent to its curve. It is by attention to the optical effects produced by the impact upon one another in nature, that the artist can alone store his mind with the most graceful varieties of delicate contrast. Thus it is alone that he can appreciate the extreme beauty of her constant, minute, and generally inappreciable divergence from the precise mathematical figures, in approximation to which simplicity demands, as we have already shown, that her leading forms should be modelled.

We have now arrived at a recognition of the four principal elements which invariably concur in producing those emotions of delight, which may be regarded as infallible tests of our contact with real beauty in the productions of nature—variety, fitness, simplicity, and contrast.

9. Before leaving our consideration of these elements, we cannot refrain from drawing attention to that

which is the crowning illustration of the effects of their co-operation, the human body. That theme, upon the reproduction of the external features of which the highest powers and the profoundest study have been lavished by the greatest artists of all times.

In its structure, the anatomist, aided by microscopic examination, discovers a *variety*, to which that of the Great Exhibition was monotony itself—a *fitness*, to which the most exquisite machines therein contained displayed no parallel—a *simplicity* of external form, which, without the slightest display of all that marvellous internal mechanism, confines the whole in a space precisely adapted for the free-working and protection of every part, and yet covers all with a soft and undulating surface, the curves of which are gentleness and simplicity itself. *Contrast* between curve and curve, between one line of limb and another, produces in motion incessant *variety* of expression, still in obedience to the bounding conditions of simplicity.

10. To recapitulate the sequence of these four great impressions, we may state, that when the attention of the student of nature is first concentrated earnestly upon her works, his senses are bewildered by the variety of her charms. His first discovery will probably be that of the perfect individual fitness of some one object upon which he may fix for analysis; he will subsequently recognise fitness as universal. In perfect fitness, he will marvel at perfect simplicity; and as he becomes acquainted with normal forms, isolated or at rest, he will learn to gather general impressions when he witnesses their combination, or varying forms in contrasted action.

As from this point his experiences increase, he will begin to appreciate marvellous affinities; he will find certain conditions universally forming the basis of propriety in all imitations of nature. Thus he will recognise that she has a style of form and detail peculiar and appropriate to every material in which she works, and that this style of form and detail is, in every case, modified by the exact method in which the operations of manufacture are conducted. Of this no more perfect illustration can be given than the lines of fibrous reticulation, which constitute the substance, and, at the same time, form the ornament of every leaf that blows. In the aggregate of every class he will trace general character, while the slightest variety of structure will, infallibly, be testified by some change in external outline. Gradually form will become with him an index to all leading attributes—a clue by which he will at once recognise the relation of bodies, or their properties, to one another. Thus, from form alone he will soon discern at a glance of what materials, and how, any particular object he may examine has been executed. This index or clue, be it remarked, never misleads; the "lamp of truth" never in nature burns dimly, nor with fallacious fires—never refuses to illuminate those who incline to learn in a truthful and reverential spirit. One material in her productions never looks like another. Rocks have their rugged outlines; minerals their appropriate crystals; metals their colours and glittering aspects; timber its bark and cellular section; flowers their delicacy and evident fragility; even transparent bodies their varying angles of refraction; water its glassy surface when at rest, and unmistakable curves when agitated. Never does a flower look like a piece of metal, never a piece of timber like a rock.

11. As the student's acquaintance with these consistencies in nature increases, his power of generalizing will become developed. He will learn to separate constants from accidents, and to trace the distinctive lines which convey the idea of each general family of materials, or modes of formation. He will begin to select, and to treasure up in his memory, those symbols of expression with which nature indicates the leading characteristics of every variety of object she produces. On the amount of the artist's acquaintance with such conventionalities, or, in other words, with the written language of nature, will entirely depend his possible success in producing by his labours sensations of delight at all equivalent to those excited by the aspect of her noblest works. Direct imitation will do next

to nothing—fanciful and ignorant invention still less; it is alone by his power of wielding her weapons of expression, and making in all cases the form and the object strictly concordant, as she does, that the artist may aspire to emulate the power of giving delight, which, above all others, appears to be her paramount prerogative. Time will not permit our dwelling further upon the general inferences deducible from a study of the wonderful beauties of nature. Enough, however, have been enunciated concerning the most palpable principles, to warrant our assertion, that there exist conditions of harmonious relation which pervade the most exquisite forms in Divine creation.

DIGBY WYATT.

LESSON II.

COLOUR IN THE DECORATIVE ART.

BY OWEN JONES.

1. *Colour is used to assist in the development of form, and to distinguish objects or parts of objects one from another.*

The most cursory glance at the works of Nature will establish the truth of our first proposition. We see everywhere in nature colour assisting form, in producing distinctness: thus, flowers are separated by colour from their leaves and stalks, and these again from the earth in which they are planted; and, not to fatigue you with examples, it is at once evident how much in nature would be meaningless, but for the many charms of colour spread over the earth so lavishly.

Had nature applied but one colour to all objects, they would have been indistinct; but, by an ever-changing variety, each has its proper tone and hue, from the modest lily of the field to the parent of colour, the glorious sun in the heavens.

The ancients ever obeyed this law: thus, the capitals of their columns are separated by colour from the shafts; and these, again, by colours from their bases or pedestals.

2. *Colour is used to assist light and shade, helping the undulations of form by the proper distribution of the several colours.*

But for light and shade we should have been unable to recognise the distinctive forms of objects: without it a globe would be but a circle, the light on the exposed surface, and the shade on the retiring surface alone convince us of its rotundity.

We find, therefore, in nature's works colour assisting light and shade; by its help the modulations of form are rendered more apparent; were it otherwise, it would be to little purpose that the flower should be distinguished by colour from the leaf, if the individual form of the flower and the leaf had been extinguished in the process.

3. *These objects are best attained* (i. e., objects or parts of objects are distinguished one from another, and the undulations of form are assisted) *by the use of the primary colours on small surfaces, and in small quantities, balanced and supported by the secondary and tertiary colours on the larger masses.*

This proposition will not so readily be accepted as the two preceding. There are many who will object that the primary colours are the delight only of the savage and the uncultivated; but I answer, that the primary colours are never vulgar or discordant when properly applied; the defect will lie, not with the colours, but with the want of skill of the hand that applies them. They must be used as in nature with a sparing hand, on small surfaces, and in small quantities; the secondaries and tertiaries in larger masses, and on larger surfaces, atoning for their lesser brilliancy by their greater volume.

We find in the works of the Egyptians, Greeks, Arabs, and Moors, during the best periods of their art, this beautiful law invariably followed; but, on the contrary, when the art of each civilization declined, the primaries are no longer the ruling harmonies; the secondaries and tertiaries from being subordinate, became dominant, and muddiness and indistinctness resulted.

In Egypt, during the reigns of her native kings, the primaries mainly prevailed; whilst under her Greek rulers art languished, and being practised rather from imperfect tradition than from poetic inspiration, the secondaries usurped the place of the primaries, and the beautiful harmonies which had before been produced by their combination were lost.

The progress to further decline is again remarkable under the Romans, who taught the Egyptians to build up temples of greater magnitude, with stones more nicely fitted, with the mechanical processes more advanced, but with the poetic fire wanting, and nought but a barren work of skill remaining.

The same decline may be observed with Greek architecture. In the temples of Greece, as far as we are acquainted with them, the primaries were dominant; whilst in Greek towns, under Roman rule, the true principles of their noble ancestors were thrown aside, and the caprices of the Roman masters substituted.

When the truly enchanted palaces of the Moors fell into the hands of the Catholic kings, who despised a civilization they were unable to appreciate, the true principles which the Moors had learned in their worship and observation of nature's works were despised and rejected, because, as now, not understood. Their blues and reds were repainted with green and purple, without law or reason.

Trace the history of our own Gothic buildings of stained glass, turn over the pages of the illuminated MSS. of every age, you will find everywhere the same cause at work.

"Each civilization in the ascendant goes to nature for its principles, and enriches its own inventions with the choicest conceptions of antecedent ages; while for this admirable union of conscientious erudition and fertile originality, declining civilizations substitute only a series of decrepit, disordered, and faithless caprices.

"We possess the inestimable advantage of living in an age when nothing of the past remains a secret; each stone of any monument of every clime has told its tale, which is now brought within the reach of our own firesides: yet, hitherto, how little have we shown ourselves worthy of this great privilege! The ease with which our knowledge might be obtained has made us indifferent of its acquirement, or led us to substitute an indolent and servile imitation for an intelligent and imaginative electicism."*

4. *The primary colours should be used on the upper portions of objects, the secondary and tertiary on the lower.*

This proposition, founded also on observation of nature's works, was generally obeyed in the best periods of art, but nowhere so well or so universally as in the buildings of the Moors, who confined the primary colours entirely to the upper portion of their buildings, and the secondary and tertiary to the lower. In Egypt we do see, occasionally, the secondary (green) used in the upper portions of their temples; but this arises from the fact that ornaments in Egypt were symbolical and more nearly represented natural objects than in other styles. If a lotus-leaf were used in the upper portions of a building it would necessarily be coloured green, but the law is true in the main: the general aspect of an Egyptian building gives us the primaries above and the secondaries below.

Even in Pompeii we find this sometimes: in the interior of their houses there is a gradual gradation of colour downwards from the roof, from light to dark, ending with black; but this is by no means so usual as to convince us that they felt it as a law, for there are many examples of black immediately under the ceiling. This law will be found of great use in the decoration of the interiors of our dwellings. Ceilings and cornices may be decorated with the primaries of prismatic intensity on the small surfaces of their mouldings; the walls, on the contrary, from presenting larger masses, should be of secondary colour, of low tones and hues. The dados still stronger in colour, and more broken in hue. The carpets should be darkest of all, composed of broken secondaries and tertiaries, so interwoven and neutralized that they retire from the eye, both as furnishing repose for the colouring of the upper portions, and as backgrounds to the furniture placed upon them.

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* "Journal of Design" for June, 1851.

5. *The various colours should be so blended that the objects, when viewed at a distance, should present a neutralized bloom.*

Colours should not only be used in certain proportions, but they should be so interwoven that no one colour should attract the eye to the exclusion of the others; when viewed at a distance they should melt into one another.

In the Oriental patterns we find this result invariably attained; they seem ever awake to correct the least tendency of any one colour to overpower the others: for instance, it is very common with them, when they have a massive gold ornament on a coloured ground, to allow the ground colour to reappear on the gold ornament, as another ornament: so that not only the volume of gold, when in excess, is thereby lessened, but the ground colour is carried into it, so that a perfect balance is obtained.

6. *No composition can ever be perfect in which either of the three primary colours is wanting, either in its natural state or in combination.*

This is evident. Blue and yellow, red and yellow, red and blue, would be discords; so green and yellow, purple and blue, orange and red: yet each of these discords may be resolved by the interpositions of neutrals white or black, which contain all colours in the positive or the negative state.

They are also harmonized by the interposition of metallic gold, of which more hereafter. They, of course, may exist on parts of objects, if the third colour is so near at hand as to be comprehended in the same glance.

7. Mons. Chevreul, by a series of experiments carried on for a number of years, established the fact that colours juxtaposed influence each other in a most remarkable degree. He establishes two kinds of contrast; the one, contrast of tone, or the modification which each colour suffers in intensity; the other, contrast of colour, or the modification which each colour suffers in hue.

He tells us, that all coloured bodies, besides reflecting the coloured rays proper to their particular colour, reflect a certain number of white rays and a certain number of others, which are complementary to the colour of the particular bodies: for instance, a red body, at the same time that it reflects red rays in a large quantity, reflects also white rays and a certain number of green rays.

It will be evident how valuable a perception of this law of contrast must be to any one engaged in any way with the employment of colour, as any colour can be subdued or heightened in effect by juxtaposition.

In fact, colours are mere relative terms; they change at every instant, that which appears deep-red when compared with an orange-red, becomes orange-red when compared with a still deeper-red.

8. There has often been much discussion upon the propriety of imitations in decorative art, such as imitations of the graining of woods and various coloured marbles. There is no doubt that, of late years, the skill obtained by our artizans in producing these imitations has caused the practice to be very much abused, but it need not for that be entirely discouraged.

The principle which should regulate the employment of imitations has never yet been defined; it appears to me that *imitations are allowable whenever the employment of the thing imitated would not have been inconsistent.*

For instance, there can be no objection to grain a deal door in imitation of oak, because the mind would be perfectly satisfied if the door were oak; but it would be an absurdity and abuse of means to paint it in imitation of marble.

Again, the practice of covering the walls of halls and staircases with paper in imitation of costly marbles, is very objectionable, because the employment of marble, to such an extent, would be inconsistent with the character of most houses, and, consequently, the sham is much too glaring: on the contrary, were the pilasters and columns of a hall only painted, the objection would cease, seeing that the mind would be satisfied with the reality. A violent instance of the abuse of graining existed formerly in the Elgin Room at the British Museum, where beams on the ceiling, thirty feet long, were splashed in imitation of granite. Here was a manifold absurdity, as no granite beam could have supported itself in any such situation. The door-jambs of an opening, on the contrary, might be imitation granite without inconsistency, as in such a situation granite would be useful as indicating strength.

9. *Flowers, or other natural objects, should not be used as ornament, but conventional representations founded upon them, sufficiently suggestive to convey the intended image to the mind without destroying the unity of the object they are employed to decorate.*

If our proposition be sound in theory, and be fortified by the practice of past ages, it applies with great force to the mural-decorator, the paper-stainer, the calico-printer, the weaver, and the potter; and, in fact, to all engaged in the decorative arts.

First: Mural Decorators.—It is very evident that the treatment of a picture in fresco should be very different to that of a painting in oil: in the painting in oil all the resources of art are invoked to make, as far as possible, the picture appear a reality; within his frame the painter has to himself a world, but it should be far different with a fresco; the flatness of the wall should never be disturbed; all chiaroscuro should be avoided, and the figures should be on one plane.

10. *The Paper-Stainer.*—The art of the paper-stainer has been very much neglected in this country, and is, indeed, but little better in France, although they have brought to bear upon the subject a great deal of mechanical skill in printing, and much good drawing and designing; yet it is drawing and designing mostly on false principles. It is evident that one of the first principles to be attended to in the adornment of the walls of an apartment is, that nothing should disturb their flatness; yet it is very difficult to find a paper that does not in some way violate this rule: they are either large, of conventional foliage, generally a variation of the eternal acanthus leaf surrounding patches of unbroken colour, or representations of fruits or flowers, twisted into the most unwarrantable of positions. There are specimens of English papers, than which nothing can be

more absurd,—a wall covered with repetitions of the same subject; men and horses standing on each other's heads; or steamers floating on each other's masts. You will say, they are cheap papers, below criticism; but we have a French paper, which has had a great run in this country: it is a wall of strawberries. Now, in what are the English papers more absurd than this? Beautiful as this strawberry pattern is, well drawn, well printed, the colours nicely distributed over the surface, it is yet offensive, because it violates the first of all rules—propriety.

We say, therefore, that all direct representations of natural objects in paper-hangings should be avoided; first, because it places these objects in unseemly positions; secondly, because it is customary in almost every apartment to suspend on the walls engravings or other ornamental works; and, therefore, the paper should serve as a background, and nothing on it should be obtrusive or advancing to the eye. Diaper-patterns in self-tints are safest for this purpose; but when varieties of colours are used, the Oriental rule of so interweaving the form and colour, as that they may present a neutralized bloom when viewed at a distance, should never be departed from.

The prevailing colours of the walls of rooms hung with printed paper should, of course, vary with the character of the room and the aspect. Halls and staircases look well hung with green, becasue the eye on entering a house is generally fatigued with the strong glare of daylight, and the green is the most refreshing. Studies and dining-rooms look well with dull reds in diapers or flocks, which may be enriched with gold; these form good backgrounds for engravings or pictures, but the reds or greens must never be positive colours, but low-toned and broken, so as not to disagreeably impinge upon the eye. In drawing-rooms, where the paper has to do more towards furnishing and beautifying a room, they may be more gay; almost any tone and shade of colour heightened with gold may be used, provided always that the colours are so arranged, and the forms so interwoven, that a perfect balance be obtained, and the eye never attracted to any one portion.

11. The *Calico-Printer* and the *Weaver* violate our proposition at every step. We have ladies' dresses, ribbons, furniture-prints, carpets, which are the more and more admired from the perfect knowledge of botany they display, violating the sense of propriety at every step; we walk on flowers and tropical plants, crushing beneath our feet; we have chintzes covered with roses, in violent contortions over the sinuosities of our furniture, or broken in twain by the folds of curtains; ladies robed in rose, shamrock, and thistle (a high achievement); the fast man, with race-horses printed on his shirt, and pointers woven on his neckerchief.

The *Potter* keeps pace with his fellows; without his flowers he believes his art would cease to be; with him consistency is disregarded, he serves us flowers with every dish, magnified and microscopic.

So runs the fashion of the present day; would that its sun were set, that we might awake to a more healthy dawn!—Owen Jones.

Outlines of Musical Study.

BY HENRY F. CHORLEY.

LESSON I.

INSTRUMENTAL MUSIC.

1. Let us now speak of Instrumental Music. In this branch of music progress has been capricious, and perfection not simultaneous; and here, again, and more largely perhaps than in any other section of the art, is it necessary to separate the creator from the executant, and music of thought from music of exhibition.

2. In the history of modern instrumental, as well as of vocal music, it will be found that the study of science and harmony preceded that of melody. The oldest instrument, almost, which has a great and real value, is the Organ; since the Harp is essentially an instrument of accompaniment, employed to contrast with and to support the voices; whereas the organ, though resembling, in its many tones, the vocal chorus, wa

early promoted to a separate existence, and found capable of affording a pleasure of its own when voices were silent—a pleasure, too, totally independent of the dance, to which its comparatively grave and heavy tones rendered it an ineligible companion. Owing to the power which the hands possess of striking several notes at once, the organ became an orchestra or concert-machine commanding eight or ten distinct parts, while its capacities of including many qualities of sound afforded yet further temptations to the solitary musician, who could grasp of his sole self, more varieties of effect, within a certain limit, than were otherwise attainable.

3. It is true that the organ is an assemblage of fifes and clarions, and that the separate wind instruments capable of producing a call of single notes preceded it; but they were rude, harsh, and imperfect, offering in their disunited state little scope or temptation to the composer, and largely devoted to the imitation of the human voice, or to the sounds of nature, such as echoes and winds. Whenever the pipe was used to inspire the dance, the rhythm had to be marked with tabor or wire, as producing quicker, more certain, and more brilliant sounds. The organ, then, perfected out of the rustic bagpipe, was perhaps the first instrument for which the trained instrumental musician—as distinguished from the uncultivated peasant—wrote.

4. Long before the orchestra was collected, the organ was in complete being; and instrumental counterpoint (or the adjustment and sequence of divers parts forming one whole) found full expression among the combinations of its stops, and on its keyboard, for hands and feet. The first of music's great instrumental composers, John Sebastian Bach, as a composer of organ-music, has never been since approached in learning, in variety, and in thorough understanding of the language in which (to speak figuratively) his majestic and vigorous thoughts were expressed. He wrote for other single instruments also, and for combinations of instruments. It is true he wrote for them nobly, but often experimentally: whereas, on the organ he is like a king

on his own domain, making conquests, giving laws, establishing models and usages. In spite of all that modern mechanical science has done to smooth some of the severest difficulties of the instrument—and in spite of all that modern fancy has struck out, in the culture of a more melodious, more expressive, freer form of rhythmical melody—Sebastian Bach appears to have indicated all that could be conveyed by that vehicle of utterance to which he addicted himself.

5. But the organ, like all other instruments belonging to the solitary player, is an instrument of exhibition as well as one merely expressive of musical thoughts, and as such could not be thoroughly well composed for by one who had not considered and mastered all its mechanical difficulties. Bach was, in fact, *the* greatest of organ-composers, because he was also *the* greatest of organ-players. He knew that his own ideas would be imperfectly shown off unless his instrument also was exhibited advantageously.

6. The imperfections and peculiarities of the organ, the incorrectness of its intonation, which can only be concealed, never wholly overcome—the contradictions of sonority, which, when its full strength is put forth, make that which under other circumstances would be cruel discord, a rich and glorious harmony—are subjects which may be pointed out to you as claiming attention and labour, should the organ be the instrument chosen by you for study.

7. The Harp has been already mentioned, as named by the side of the organ in the earliest notice of music. In some rude form stringed instruments played on by the hand, were among the most primitive materials for music. The harp, let us repeat, is a more poetical than practical instrument, since this very manner of playing it limited its powers. Although its structure has undergone vast mechanical improvements of late years, variety of execution and rapid change of combination are still so difficult, that it probably always must remain chiefly valuable as an accessory or accompaniment. It is impossible here to enumerate the adaptations and modification of the harp—such as lute, lyre, guitar—

all instruments of more or less compass, the strings of which were made to sound by the pinching of the fingers. Some inventor, to relieve the hand, bethought him of applying a secondary means of touch. The introduction of rods or hammers, to strike the cords or sinews which served for strings, sharply, produced the Dulcimer. The discovery of the bow, which, being drawn over the strings, gave birth to prolonged sounds, created the Viol and all its manifold family, which, as a group, form the basis—or heart, or kernel, as the case may be—of the modern orchestra.—We shall for a moment return to these, but must now dwell on the dulcimer. After it was found that effects could be produced by striking the strings with rods, it was further discovered that the action of such rods could be regulated and extended to inconceivable variety, by connecting these with keys, after the fashion of the organ, whose pipes are thus made to speak. Hence came the spinet, the harpsichord, the pianoforte; and with these fascinating instruments—of all others the best for solitary pleasure and domestic use—a treasury of compositions, in which with little less nobility of idea than the organs claim—delicacy of form, intricacy of ornament, and versatility of effect, could be largely combined.

8. These keyed instruments, besides furnishing delicious materials for the musical thinker, have a great value in their power of affording representations and transcripts of music in more vast and complicated forms. Besides the field of their own, which is separate and full of beauty, they offer to the musical student a pleasure and profit analogous to those offered by the engraving to the lover of pictures. Without the grandeur of the organ, they are also without its unwieldiness; without its sustained tones, they are more susceptible of expressing the moods of the player: since every different player's finger produces a different quality of sound on the same instrument, whereas on the organ it will only produce a different division of accent.

9. It is impossible to touch on music for keyed instruments without pointing out the debt that is owing to

Domenico Scarlatti (born in 1683, and the son of Alessandro Scarlatti, a great composer of vocal music) for the amount of variety, resource, and acceptable form, that he reintroduced into his compositions for the harpsichord. He was as great a performer on his instrument as Sebastian Bach was on the organ; and is said, like a true man of genius, to have followed Handel, when Handel was in Italy, for the purpose of studying and admiring that great master's fancies in playing and composition. It may be here remarked, that in those days, the musical intercourse betwixt Italy and Germany was such that there was only one style, or school of composition; nor was it till the middle of the last century, that those peculiarities began to manifest themselves, which very soon spread and strengthened into distinct nationalities, and which entirely separate the school of musical composers on this side of the Alps from those of Milan, Venice, and Naples. The Italians (as a school of creative musicians) may be said during the last century to have confined themselves to vocal composition for the church and stage, since the writings of both Cherubini and Clementi, the one for the orchestra, the other for the pianoforte, bear no traces of the birthplace of their writers. But from Italy came much of our modern love for, and knowledge of, stringed and keyed instruments. The executive knowledge and finish of the Italians as *solo* players on several instruments, has never been exceeded. Even in the latter times, during which they have seemed unable to produce any instrumental music of combination which is barely respectable, the name of Paginini as the most remarkable executive musician of modern times, will suffice to illustrate this assertion.

10. When, however, organ and harp were divided, as it were—when the pipes of which the organ was composed, and the strings of which the harp was made up, were distributed among a multitude of players—the genius of combination suggested to the German composers that a new vehicle of musical expression and interest could be found in the band compounded of many instruments, and the masters of music, in place of thinking thought

fit to be uttered by organ and harp alone, began to invent such phrases and modulations, and forms, as demand variety of means and contrast of tones. It has been remarked already that science preceded expression in music, that the mathematics of the art were known theoretically and practically before the spirit of beauty was evoked in it; also that the earliest melodies have frequently been rhythmical ones, belonging to the dance rather than to the song. These assertions are fully justified by examining the progress of pure instrumental composition. In the works of the two inventors of modern orchestral music—Bach and Corelli—harmony or contrivance seem to have been principally cared for; and, in addition to this, the exhibition of technical skill on the part of some predominant player. Such melodies as their concert music possesses were given to the slighter portions of their works, in the form of jig, or saraband, or minuet, or other dancing measure. Orchestral music was in the hands of both of these great men formal and dry, as compared with the overtures and symphonies of their successors.

11. Haydn was, perhaps, the first among the instrumental composers, who, commanding as he did an inexhaustible fund of scientific resource, introduced into his writings, charm of melody, freedom of fancy, lightness and variety of structure, and the excitement of surprise, besides the satisfaction of reason. Haydn may be said to have settled the grouping and arrangement of the orchestra as it stands, by provingthat plurality-stringed instruments are required to balance each single wind instrument, and by determining what has been since his time accepted as the most effective manner of employing forces so widely differing in quality.

12. This great man, too, exhibited inventive genius in its highest and rarest form. Not only did he precede the generation of great German composers; but when his successor, Mozart, had improved on his discoveries, he was wise enough, though already a patriarch in renown, to avail himself of Mozart's improvements; showing an example of healthy progress to the last our of life, of which Art's annals contain too few

examples. There is no music from a perusal of which the student can learn more than Haydn's; there is none which will afford him more flights of fancy and humour to admire, and fewer peculiarities to copy.

13. Haydn was in some measure superseded and cast into the shade by his successor, Mozart. The latter, as the more universal composer of the two, and considering the entire mass of his works, as the most harmoniously accomplished and complete musician who ever existed, ranks at the very topmost height on the list of those who have given pleasure to persons of every class of intelligence. As an instrumental writer, Mozart commanded a flow of delicious melody, and employed a variety of materials, which distinguish him from his predecessors. Let it be also remembered that Mozart died at an age when many men of genius have hardly come to the fulness of their powers. There has been perhaps, in no art a more fertile, complete, and fascinating genius than his; nor one in which the mixture of learning and grace, of science and fancy, has been more happily exemplified. All such comparisons and qualifications as have been applied to his position and to his renown, belong to a stage of musical refinement and culture, beyond theirs who consult "Outlines."

14. Though Mozart, as regards symmetry and grace —a composer exercised in every style of music, sacred and secular, vocal and instrumental, for the theatre and the chamber—is possibly the most faultless of musical poets,—in point of brilliancy, novelty, grandeur as an instrumental composer, he is surpassed by Beethoven, in Beethoven's best works. The mighty genius just named, though less equable, less uniformly gracious, less thoroughly versed in the mysteries of science than Mozart, rose to higher flights of imagination, in his purely instrumental compositions, than have been attained by any one before, beside, or after, him. It may be remarked too of Beethoven, that the dignity, tenderness, and variety of his ideas, and the amazing variety of form into which he could cast them, in no respect depended on the scale or the class of his work. In his chamber music, for stringed instruments in concert, yet

more for the pianoforte alone, as much diversity of character, and versatility of language may be found, after their kind, as in the plays of Shakspeare. "Lear" is not like "As You Like It,"—we know that they are both from the same hand, merely because we know that no other hand was able to produce such tragedy or such comedy. Thus it is also with the separate productions of Beethoven.

15. The above comparison must not be made for the sake of illustration, without its being accompanied by a caution. The study of instrumental music has been much damaged and disturbed, by attempts made to force it into uses, meanings, and interpretations, of which music is not susceptible; since its language is vague, and that which shall seem to one listener distinct in its import, will by another be fancied to bear a totally different signification. There is emotion in all music—there is sentiment, sad or gay, in music without words—but there cannot be that close and minute painting of either scenes or feelings, which the imaginative have attempted to impose on it. Those who accept music best, the most closely attend to the structure of the work, and the most purely discern all that lies in its ideas and in their arrangement, are the least anxious to seek, what were precisely the outward causes, objects, and circumstances, which made the writer choose certain flats or sharps for its key, or certain forms for its melodies.

16. In Beethoven's best writings for the concert-room and the chamber, instrumental music may be said to have reached its perfection The true German spirit expressed itself there as perfectly as did Italian inspiration in the unaccompanied vocal masses of Palestrina, and in Rossini's best operas. Subsequent to Beethoven, among more modern German composers must be named Spohr and Mendelssohn; not because they have carried discovery further than Beethoven did, but because each has his own individuality, bearing no reference to that of this great master. On Mendelssohn the student will always vell, not only to study his writings, but to admire o the beauty of his life;—a life of energetic occu-

pation in his art, and of intellectual culture apart from his art—of domestic affection and domestic happiness, such as few men have been privileged to lead, whether for their own enjoyment, or as an example to others.

17. Besides the music of thought and combination for the orchestra and for the chamber, there is another form of instrumental music which is not to be overlooked—the music of exhibition for the display of instrumental accomplishment. Not merely are the *Concerto*, the *Fantasia*, the *Rondo*, the Air with variations, indispensable where ever training is sought for, to exhibit and to test the fruits of that training; they have, also, in themselves, an interest of a certain kind, when the hearer is in a certain humour. A large portion of this music can only please for a time, inasmuch as fashions in ornament pass away; the best of it, however, will endure, not merely as studies affording a basis for the works of succeeding inventors as they arise, but also as creations in which thought and beauty take a form more decorative than severe; not therefore to be contemned. There is hardly any single instrument of importance, for the display of which some masterpiece has not been written, that will never grow old; and since music is an art that requires listeners, display for display's sake must have its turn. Where elocution fails to be cultivated there no oratory is possible; and while we dwell with the strongest weight of interest on the importance of grandeur and novelty in thought, and depth in science, let it be recollected, too, that utterance must have its outlet. Besides a heart and a head, there must be also a tongue. In this point of view, the *Concerto* or *Solo* has never been neglected by great composers or thoroughly accomplished listeners.

18. In conclusion, a few detached maxims and counsels may be offered, which it may be well for every lover and student of Music to bear in mind.

19. While learning the science of music, you cannot acquaint yourself too thoroughly with all its theoretical rules, and its practical effects; while studying its models you cannot analyze them too deeply, or dissect them too

minutely;—while attempting composition you cannot too earnestly resolve to avoid imitation.

20. Unconscious imitation is better than a far-fetched or pedantic eccentricity under the pretext of originality.

21. Do not be afraid of admiring too largely. Solomon, who was the wisest of men, knew the hyssop on the wall, as well as the cedar of Lebanon. The mind has as many moods as the sky has colours, and every mood is worthy of entertainment. But do not, because you admire, mistake what is pretty for what is grand, nor mix what is permanent with what is temporary. The most pious people have been the most cheerful ones, but they have not confounded serious thoughts, and devotional enthusiasms, with the lighter fancies which flow free when the mind is at rest, and the temper is gay.

22. Remember that no pleasure is sound in which consistency and truth do not exist—that no ornament is elegant without propriety and proportion.

23. Endeavour to place yourself at the same point of view where the artist stood, when he made the work which you are examining.

24. It is worse than idle for an Englishman to say, "This must be bad because it is French, or Italian." "This must be good because it is German."

25. Some of the most admirable works of genius are among the worst models. That which is to be studied as an example, that which must be admired (even with confessed drawbacks), stand on totally different levels, and appeal to totally different sensations.

26. Believe that the happiest, best instructed, most virtuous persons, are in the best case for best enjoying art, and for producing the best works of art. It is true that too many examples of a contrary import appear to exist in music; but there exist no traces of a musician great in learning, great in fancy, great in exhibitional perfection,—*because* of his moral defects.

HENRY F. CHORLEY.

RURAL SOUNDS.

But who the melodies of morn can tell;
The wild brook babbling down the mountain side;
The lowing herd; the shepherd's simple bell;
The pipe of early shepherd dim descried
In the lone valley; echoing far and wide,
The clamorous horn along the cliffs above;
The hollow murmur of the ocean tide;
The hum of bees, the linnet's lay of love,
And the full choir that wakes the universal grove.

The cottage curs at early pilgrim bark;
Crowned with her pail the tripping milkmaid sings,
The whistling ploughman stalks afield; and hark!
Down the rough slope the ponderous waggon rings;
Through rustling corn the hare astonished springs;
Slow tolls the village clock the drowsy hour;
The partridge bursts away on whirring wings;
Deep mourns the turtle in sequestered bower,
And the shrill lark carols clear from her aërial tower.

Beattie.

The Various Forms of Poetry,

BY GEORGE L. CRAIK.

LESSON I.

THE NATURE AND ORIGIN OF VERSE.

1. It has been explained in a former paper that it is only a very small part of all that is written in any language, or even that may have been printed in it, that is to be regarded as belonging to what is properly called its Literature. Literature is, as it were, what gold and silver are among the metallic products of the earth, which are found only for the most part in the thinnest veins, or in grains, while the merely useful metals, copper and tin and iron and others, generally present themselves, where they exist at all, in comparatively large quantities.

This comparison may perhaps be made to do us a little more service in the way of illustrating our subject. It has been shown that the essence of all such writing as is entitled to the distinctive name of literature is, that it should address itself more or less to a peculiar part of our nature, or mental constitution—our sense of the beautiful. That is the sense by means of which we perceive and enjoy what is called art, whether exhibited in writing or in any other way; through which, in other words, we derive pleasure either from writing, or from music, or from painting, or from sculpture, or from architecture. And whatever is designed and fitted to afford us gratification in this manner is styled an artistic production. Or we say, to distinguish it from other productions that are merely or chiefly esteemed by us on account of their utility, that it has in it an element of poetry or of the poetical. We might say so, for instance, of a beautiful building, such as St. Paul's, or Greenwich Hospital; but not of a plain warehouse or dwelling-house, however substantial or commodious.

2. It is to literary compositions, however, that the term poetical is most commonly applied. And artistic literature, or literature considered as one of the fine arts, is usually denominated Poetry. But the poetical element may enter into a literary production in various proportions. It may be the sole or the predominating constituent of a composition, or may be very subordinate to its other qualities in quantity and importance. We might say, then, that it is with the expression of thought in words as it is with the several kinds of metals. Even those of them that are most pre-eminently useful can hardly be said to be universally merely useful, or absolutely without something of beauty too, something that the eye takes a certain pleasure in looking at; there is the pale brightness of lead or tin, or the richer colour of copper and burnished steel: so even the writing the main purpose of which is most purely useful is rarely without a tincture of something that might be called poetical or artistic. When this quality, however, exists only in very slight measure, it goes for nothing; it is only when it is a distinguishing quality that it gives an artistic or poetical character to the composition. To do this, the beauty, splendour, or uncommonness must be something surpassing and daz-

zling, like that of what are called the precious metals, —of gold, or at the least of silver.

Just as there are those two accounted precious among metals, so there are two kinds of artistic literature. There is what answers to the gold, and there is what answers to the silver. The latter in every language exists in by far the largest quantity. It is only what may be called *poetical.* It has more or less in it of the spirit of poetry. But it is only the other kind that is *poetry* properly so called. It is concerning that that we are now to speak.

3. The distinction of that writing which is fully entitled to the name of poetry is very simple. Its form must be that of verse; that is to say, the words must be arranged in obedience to some law or rule which regards merely their sound. Of course, it is not asserted that all writing which is in verse is poetry; but there can be no poetry, properly so called, without verse. This has been the sentiment and conviction, clearly and indisputably, of every nation and age in which any form of literature has been known.

Now, if we look at poetry in this light, the first thing that we shall discern in regard to it is, that it has its birth in music. It is, in fact, a kind of music. It is a music of articulate sounds, or what we call words. It is a combination, therefore, of whatever can be expressed by words with more or less of the charm of music.

4. Observe what goes on among children. In the first verses with which their awakening fancy is caught, and which they take delight in repeating, the sound is evidently all they care for; the sense is nothing. Such verses are properly called nursery rhymes: all that is required of them is, that they shall rhyme; the less they are burthened with any kind of sense, one would almost say, the better they are. What meaning the best of them have is usually as simple, not to say silly, as can be put into words. It is "Ding dong bell, The cat's in the well;"—or "Sing hey diddle diddle, The cat and the fiddle;"—or "I'll sing you a song, The days are long;"—or "See saw, Margery daw;"—or "One, two, Buckle my shoe,"—or some similar piece of

innocence. It was a strange delusion that took possession of an ingenious philological speculator some few years ago, who wrote a book to prove that all this traditionary poetry of young England, light and empty as it seems, was in reality so much heavy Dutch wisdom and wit in disguise or in ruins; that the words were Dutch words, mostly very sensible and pregnant in that language, and only made to look foolish by having been corrupted into English. The foolishness, if it must be so called, or unmeaningness, is quite natural in such compositions. Meaning, as has been said, was scarcely thought of at all in their invention. What was aimed at was, not reason, but only rhyme. Evidently the little snatch of melody had first in some way or other taken voice and shape, and had then of itself given birth to the answering words. It was a process nearly of the same kind with that by which the chime translates itself into language, and "Halfpence and farthings, say the bells of St. Martin's;—Oranges and lemons, say the bells of St. Clement's;—Two sticks and an apple, say the bells at Whitechapel;—Old Father Baldpate, say the slow bells at Aldgate;—You owe me ten shillings, say the bells at St. Helen's;"—and so forth. "As the fool thinks," it has been said, "so the bell clinks." But that is an austere judgment. There is no peculiar folly in such fancies; only a certain naturalness, or childhood of the heart, which it would be all the better for the wisest of us never altogether to lose.

5. But in this way it is that verse must have taken its beginning,—verse, which may be called the matrix or mould of poetry. It sprung from music. The first verse was nothing more than a conversion of the airy notes into articulate sounds, whereby the ear and the mind might get as it were a firmer hold of them, and they might acquire a more substantial and secure existence. It was something like what is still practised in singing under the name of *sol-fa-ing*, in which the notes are expressed by *ut*, *re*, *mi*, *fa*, *sol*, *la*, or some other succession of equally unmeaning syllables. In some of the rudest of our popular rhymes the words have very little more either of sense or of syntax than we have in this

technical contrivance. Whenever we take to utterance by means of words, however, we cannot long escape falling into the natural course of speech, which is to express always some meaning, however little. Let any one try, and he will find how difficult it is to go on long uttering mere unconnected words, even if they should be no better than "ding, dong, del,"—or "hey, diddle, diddle." The tendency to strike into sentences,—short, it may be, and slight, and little burthened with sense, but still, after a sort, grammatical and intelligible,—immediately becomes inevitable. This, then, is the first thing that happens. The little tune gets sung, not to mere articulate sounds, but to a succession of words and syllables arranged as words usually are in speech. The element of meaning has now combined with the merely emotional element of music. It may be meaning of any kind,—much or little, profound or shallow, serious or comic. It is practically discovered, whether theoretically recognized or no, that any kind of meaning that can be conveyed by words may be so conveyed with the addition of musical expression. Still, however, the words, whatever meaning they may have, are words to be sung. That is an essential part of the first conception of verse. The words have their measured form for no other reason. They are used simply to give a more definite character to the music. Hence it is that poetry or verse is still in every language commonly known also by the name of song, or some equivalent designation. Originally it was always sung. And all poetry to this day retains certain conventional phraseologies derived from this its primitive condition of subordination or vassalage to music. Thus Homer invokes his divine muse to *sing* the wrath of Achilles; Virgil begins his Æneid by announcing it to be his intention to *sing* the adventures and exploits of his hero; the same style is common in all the romantic poetry of the middle ages, French, English, and Italian; and so our own Milton, delighting most of all poets in this genealogy of his art, has filled his great epic with expressions of similar import:—"*Sing*, Heavenly Muse;" —"My adventurous *song*;"—"I *sung* of Chaos and eternal Night;"—"Still govern thou my *song*, Urania;" —"Since first this subject for heroic *song* pleased me, long choosing and beginning late;"—and others.

6. And now here, before we go on, let us take note of one thing. In another of his poems Milton has spoken of this assumption by music of the stay of words as a marriage between the two: "Lap me," he says, "in soft Lydian airs married to immortal verse." And it is, in fact, the verse, not the air, that has in any case proved immortal. Much of the word-poetry of antiquity still survives; but all the mere music has perished. We may say, therefore, that that which ancient song took to itself only as a crutch to lean upon has, after all, proved its preservative, in so far as it is preserved. The music alone was too aërial and delicate a thing to live through such a tempest as that by which the civilization of antiquity was thrown down; it was only as it were a kind of splendour in the clouds, which could not but die with the sunlight; the words to which it was wedded might give it at least such immortality as can be conferred upon whatever has once been beautiful by its embalmment, or enshrinement rather, in the painter's colours.

7. But soon a second thing would happen. It would be found that the words, originally adopted as a support for the music, and only for its sake arranged and measured so as to accord with the music, might also be so managed as to have an interest and attractiveness independently of the music. On this, in some cases, verse, originally the offspring of music, and responsive to it, would be separated from it, and declaimed or recited alone; in others, verse would be composed without any reference to a musical air. In either case, simply in virtue of being verse and not prose, it would still have a certain music of its own—a music differing in kind from that distinctively so called, but yet far from being without a power both of touching the heart and charming the sense. This should not be called the separation or divorce of poetry from music; that union has never been broken; it is still the highest and most perfect condition of both; but yet we may say that the

release of verse from the rule and authority of its parent, music, and its acquisition of the right of going forth and doing for itself, was such an emancipation as was required to enable it to know how great a thing it was, and to call up all its powers. It was like what leaving the shelter of the parental roof for the wide world is to the youth ripe and eager for the battle of life. Not till now had poetry put off its chrysalis state, and spread its wings.

8. But still poetry in all its forms partakes, and ever must partake, of the nature of that from which it is sprung. It is essentially something musical. And the truest and deepest kinds of poetry have the nearest alliance with music, and the most of its spirit.

First of all, there is what is called Lyric Poetry, or poetry written expressly to be sung, and which, in its most intense passages is only half enunciated if it be merely recited. Even facts and history attest that this is the most ancient kind of poetry, and that out of which every other kind has arisen. Among the Greeks, at least, from whom through the Romans the main stream of the literature of modern Europe is ultimately derived, both Dramatic and Epic poetry appear to have been originally lyrical. Their first drama was a contest in singing; their oldest epic or heroic poetry was chanted to the sound of the harp.

9. Now these three,—the Lyric, the Dramatic, and the Epic,—are the chief and ruling forms of poetry. All other kinds are only subdivisions of or derivations from these. The two latter appear to have branched off from the first, and to have acquired their distinctive characters and names, in this way. Where the singing was accompanied, not merely by the sound of the lyre, but by movement on the part of the singer, or dancer, the spirit of performance or acting gradually insinuated itself more and more into the exhibition, till at last that came to be recognized as its principal or almost sole purpose; to favour and promote which, first a second and then a third performer were introduced. Hence the birth of dialogue; the music produced the dancing, and the dancing produced the dialogue.

Where, again, from the poetry taking the form of a narrative, the music was necessarily reduced first to take a very subordinate place, as it naturally does in a ballad as compared with what is properly called a song, and at last to give way altogether to the mere recitation, the composition came to be regarded as rather intended to be spoken or declaimed than sung or otherwise musically accompanied. This is probably the true, though it is not the common, explanation of the terms Dramatic and Epic:—poetry was called dramatic which was to be acted, and epic which was to be spoken. Lyric poetry, of course, was that which was especially adapted to be sung, and to be accompanied by the lyre.

THE YOUNG POET.

And yet poor Edwin was no vulgar boy;
Deep thought oft seemed to fix his infant eye;
Dainties he heeded not, nor gaud, nor toy,
Save one short pipe of rudest minstrelsy;
Silent, when glad; affectionate, though shy.
And now his look was most demurely sad,
And now he laughed aloud, yet none knew why:
The neighbours stared and sighed, yet blessed the lad;
Some deemed him wondrous wise, and some believed him mad.

Lo! where the stripling, wrapt in wonder, roves
Beneath the precipice o'erhung with pine;
And sees on high, amidst the encircling groves,
From cliff to cliff the foaming torrents shine;
While waters, woods, and winds, in concert join,
And echo swells the chorus to the skies.
Would Edwin this majestic scene resign
For aught the huntsman's puny craft supplies?
Ah, no! he better knows great Nature's charms to prize.

And oft he traced the uplands, to survey,
When o'er the sky advanced the kindling dawn,
The crimson cloud, blue main, and mountain gray,
And lake, dim-gleaming on the smoky lawn;
Far to the west the long, long vale withdrawn,
Where twilight loves to linger for awhile;
And now he faintly kens the bounding fawn,
And villager abroad at early toil:
But, lo! the sun appears! and heaven, earth, ocean, smile.

And oft the craggy cliff he loved to climb,
When all in mist the world below was lost—
What dreadful pleasure! there to stand sublime,
Like shipwrecked mariner on desert coast,
And view the enormous waste of vapour, lost
In billows, lengthening to the horizon round,
Now scooped in gulfs, with mountains now embossed;
And hear the voice of mirth and song rebound,
Flocks, herds, and waterfalls, along the hoar profound.

Oft when the winter storm had ceased to rave,
He roamed the snowy waste at even, to view
The cloud stupendous, from the Atlantic wave,
High-towering, sail along the horizon blue;
Where, 'midst the changeful scenery, ever new,
Fancy, a thousand wondrous forms descries,
More wildly great than ever pencil drew;
Rocks, torrents, gulfs, and shapes of giant size,
And glittering cliffs on cliffs, and fiery ramparts rise.

Thence musing onward, to the sounding shore,
The lone enthusiast oft would take his way,
Listening, with pleasing dread, to the deep roar
Of the wide-weltering wave. In black array
When sulphurous clouds rolled on the autumnal day,
Even then he hastened from the haunt of man,
Along the trembling wilderness to stray:
What time the lightning's fierce career began,
And o'er heaven's rending arch the rattling thunder ran.

Meanwhile, whate'er of beautiful or new,
Sublime or dreadful, in earth, sea, or sky,
By chance or search, was offered to his view,
He scanned with curious and romantic eye.
Whate'er of lore, tradition could supply,
From Gothic tale, or song, or fable old,
Roused him, still keen to listen and to pry.
At last, though long by penury controlled,
And solitude, his soul her graces 'gan unfold.

BEATTIE.

LESSON II.

NATURE OF POETRY.

1. ALL that has as yet been said, it will be observed, has had respect to the proper shape or outward form of poetry. Such outward form is one variety or other of

that arrangement of words in reference to their sounds which is called verse. Is this all, then? the reader may ask: is there nothing more in poetry than verse, nothing except merely a certain outward form? Is there no internal constituent principle of poetry? Verse may be the body of poetry; but has it not also a soul?

2. Most undoubtedly it has. But it is with poetry, or with any other form of the artistic, as it is with everything else, every organization or product that manifests itself to the senses; the sensible manifestation is at once the controlling law, and the only appropriate expression of the inner animating principle. It is with poetry as it is with man himself, the poet. In describing the human being, and distinguishing him from other animals, it would be hardly possible to begin otherwise than by the mention of that most remarkable fact, his erect form. The Latin poet, Ovid, one of the sweetest of the singers in that old tongue, in the famous passage in which he gives his pagan account of the creation of man, dwells emphatically on that distinction as the chief sign of his sovereignty, and the necessary condition of his mental superiority. A modern German speculator, the ingenious and eloquent Herder, in a work which has been translated into English, his 'Outlines of a Philosophy of the History of Man,' taking up the same view, and carrying it out in the light of modern science, has endeavoured to explain in detail how even such a mind as man has been endowed with would have been cramped, and, as it were, half smothered, and rendered comparatively inefficient and useless, if it had been lodged in any other than the actual human form.

Even so it would be easy to show that the spirit of poetry finds its perfect expression only in verse, and that, deprived of that advantage, it is comparatively only what the mind of a man would be confined in the body of a beast.

3. The distinction between the poetical and the prosaic in conception is simply, that prosaic conception looks at things as they are in themselves, poetic as they are more or less metamorphosed by the intermixture of

something proceeding from the mind by which they are contemplated. The former seeks only the real and the true; the latter, something in addition to that. The poet always takes what may be called an impassioned view of things. He sees everything through the coloured light of his own feelings. Nothing is anything to him without more or less of that irradiation of which his own mind or eye is the source.

4. If this transforming influence were in every case only something peculiar to the individual poet, the exercise of his power might afford him a solitary enjoyment, but it could give him no hold upon his fellow-men. This, however, is not the case. The atmosphere of passion through which the poet looks, is made up of feelings and affections, which, in different degrees of strength and development, are common to all men. What he has acquired, in addition to his larger natural endowment of sensibility and creative fancy, and chiefly through that, and what ordinary men want, is the faculty and the skill which enable him by his representations to call up such passions as he wishes in other hearts, and to control and direct them at will according to his purpose. He is the lord of the magic glass; but most other men have also the capacity of looking through it when he holds it to their eyes, and seeing more or less of what it has to reveal.

5. It is true that what they thus see is in so far an illusion. The power of so seeing has been obtained by their eyes having had, in the phrase of the old popular philosophy of the north, the *glamour* cast over them. They are in a manner bewitched. The supernatural illumination, in which they are made to see things bathed, is a false show with which they are cheated. It is, literally, the beauty and the splendour of a dream; —that is to say, it belongs not really to the objects, but is showered over them by their own excited minds, of which it is altogether the creation. And if a man be incapable of being thus excited, he will indeed, it may be admitted, escape being deceived by the representations of poetry, but he will also remain dead to the

enjoyment of poetical composition. It will be his, it may be, to see things in what the ancient philosopher called the dry or pure light, but in that only; he will be able to see nothing in what the same authority called moistened light, or, as our own Bacon has rendered and explained the expression, "light steeped in the humours and affections." Now, the man, on the other hand, who can look at things in the latter light is by no means thereby incapacitated for also seeing whatever he wishes so to see in the former. If he is deceived by a poetic representation, it is because he chooses and allows himself to be deceived. It is not a weakness under which he is subdued, but a power which he possesses. Such being the case, it may not be quite so clear that the advantage is upon the whole with him who is proof against the spell of this enchantment. One might be rather inclined to side with the old rhetorician whose saying is reported by Plutarch, that tragedy (as he put it, but he might have said the same thing of poetry in all kinds) is an imposition, in which they who cheat us are honester than they who do not cheat us, and he who is cheated is wiser than he who is not.

6. To him to whom it communicates none of the excitement out of which it has sprung, poetry must always appear more or less extravagant and absurd. The words of the poet can only seem to be true and applicable and appropriate to those who share the emotion by which they have been prompted. If that emotion be something so strange to them, or so alien to their nature, that they have no sympathy with it, and cannot even conceive it to be possible that they should ever themselves be affected by the like, the most apt and natural expression of it will be unendurable or unintelligible. Even its naturalness may possibly not be believed in; it may be regarded as nothing more than so much hollow affectation, a pretence and a lie: or, if its sincerity be not doubted, it will sound to them as the eager talk of those who are heated and exalted with wine does to a person who is perfectly sober and cool-headed.

7. All emotion involves something of what may be

called illusion. At any rate, whatever is looked at in a state of emotion or passion presents more than is perceived by the mind in an unexcited state. Thus, to take the commonest case that can be cited, the lover sees in the object of his affection much more than is visible to ordinary eyes. It might, perhaps, be argued that it is the ordinary eyes that are blind, or purblind; lovers generally might be inclined so to argue; but the more probable hypothesis would seem to be, that that which they alone perceive is not really in the object, in which case all others would perceive it as well, but is an addition which they themselves make to the simple reality. In other words, it is the creation of the excited mind to which alone it is perceptible. It is not anything which actually exists, but only something which is imagined.

8. Now it is the imagination which is the fountain of all poetry. There can be neither production of poetry nor enjoyment of it without the imagination being called into activity. There must be so much excitement of the mind as to enable it to invest what it contemplates with colours or qualities other than belong to it in nature.

9. Is, then, all passionate or imaginative feeling poetry? Far from that. Every one is familiar with the passage in Shakspeare in which he affirms that—

> "The lunatic, the lover, and the poet
> Are of imagination all compact;"

that is, are wholly compacted or made up, or rather, perhaps, are all of them made up, of imagination. But the deep and comprehensive philosophy of this enumeration has hardly been sufficiently appreciated. Imaginative emotion or conception is indispensable to poetry. It is what we may call the raw material of poetry. But it may be nothing more. Both the lover and the lunatic resemble the poet, in that imagination is at work in them as well as in him. But that is all. They all three set out, as it were, from the point of imaginative excitement. That starting-point is what they have in common. And the remarkable thing is, that the three instances which

Shakspeare brings forward exhaust the possible forms or species of imaginative excitement or emotion. There are the three kinds of which he gives these examples or illustrations, and there are no more.

10. A man may have his excited imagination under his control, or he may not. He may possess it, like a faculty; or he may only be possessed by it. And in the latter case, he may be carried along by it with his assent, or in spite of himself. There are no other possibilities. Now, only he to whom his imagination is a faculty, which he has under his command, and which he can apply and make to do his bidding like any of his other faculties, is a poet; while he whom, on the contrary, his imagination rules and drives, is a lunatic; and the lover, again, may very well stand for the representative of all those in whom some imaginative view or emotion to which they resign themselves becomes, as it were, part of themselves, and carries their whole nature along with it, without being necessarily attended with any kind of activity or productive energy.

The three kinds of excitement or inspiration may be compared to the only three ways in which a man's person can be carried along. The poet is the expert rider, who can "turn and wind his fiery Pegasus, witching the world with noble horsemanship;" the lunatic is he who has got mounted on a horse that has run away with him, and is about to plunge with him, it may be, over a precipice; the lover is the ordinary traveller drawn along in a carriage, the motion of which he never thinks of either guiding or resisting any more than he does that of the blood in his veins.

11. The poet, then, wields his faculty of imagination with a certain art. The proper meaning or original idea of art appears to be fitness. It is the most perfect adaptation possible of every part to every other part, and to the whole. The term has been thought to be derived from the same root with that by which the Greeks denoted what we call virtue, or the essence of moral excellence. What virtue is in moral disposition and conduct, art is in invention and contrivance. It is

the highest and most complete suitableness. This is the object of all art. Handicrafts of all kinds are called the mechanical arts. The various branches of learning and science used to be called the liberal arts; that is the application of the term which we have in the academic designations of Master of Arts and Bachelor of Arts. Finally, there are what we call the Fine Arts, and our French neighbours, by a better phrase, *les Beaux Arts*, meaning the arts having to do with the production of the Beautiful. They have also been called the Imitative Arts. The best name would be the Imaginative Arts. It is to the practitioners of these last that, in English, the name artist is confined; the practitioners of the mechanical arts are called, by way of distinction, artizans. Poetry, as has been already explained, is thus, as one of the Fine Arts, a branch of the artistic, and the poet, like the musician, the painter, the sculptor, and the architect, is an artist.

12. The art of the poet consists in expressing the imaginative by words; as that of the painter consists in expressing it by colours, and that of the musician by inarticulate sounds. And in all cases artistic expression must be understood to include also artistic conception. The two things, in truth, are one, or are only two parts of one and the same act. In poetry, at any rate, there can no more be conception without expression, than there can be expression without conception. The poetical conception only attains its completion and proper being in the act of expression; it can have neither shape nor consistence till it assume the form of words. Mere emotion or vision-seeing is, let it be repeated, but the raw material of poetry. It is what the poet has in common with the lunatic. The poet, no doubt, has a capacity of producing this raw material of his art beyond other men; his imagination is more original and powerful, more active and brilliant, than theirs. And it is conceivable that a mind so endowed may at the same time be without any superior faculty of eloquence; it may have had no access to or training in any worthy form of human speech, or it may even

have been imprisoned in a corporeal organization which has made an acquaintance with any form of human speech impossible. Its possessor may have been both dumb and blind from his birth. But, if even in such circumstances the power of thought could ripen and wax strong, the most poetically creative imagination, so shut out from all use and knowledge of language, would be equally precluded from the production of poetry. For poetry is neither thought nor imagination simply, but imaginative thought expressed in accordantly musical or measured words.

13. And the music or measure of the words, or what is called the verse, is as much a part of the expression, and therefore of the poetry, as their meaning. To the full expression of passionate thought, rhythm and cadence are not less essential than words. Or rather the expression flows into a certain rhythm and cadence as naturally and necessarily as it does into certain words. We see something of this even in our most ordinary talk. But take any artistic composition, whether in verse or in prose, and disregard or systematically violate, in reading it aloud, the intonation and emphasis which properly belong to it; only pronounce what has been dictated by sad or solemn sentiment with the accent of levity or cheerfulness; and the effect is as completely destroyed as if other words were substituted. In verse, which is the artistic in words carried to the highest point of refinement, the accordance between the sentiment and its vocal utterance rises to be a matter of supreme importance. Such accordance is here demanded in every minutest fibre of the expression. No ear or heart, having any feeling for poetry, could fail to be sensible of the incongruity that would in most cases be produced by the transformation of any poetical composition into a kind of verse altogether different; the new form of verse, instead of a natural expression of the sentiment, would be apt to become a ludicrous mimicry or mockery of it. The natural correspondence or relationship between the sense and the sound in poetry is thus far universally felt and recognized. But it goes much farther than this. It is not merely that, of the various

kinds of verse, one is adapted to what is lofty or tender in sentiment, another to what is light or comic, and that the tone and spirit of the sentiment, to be effectively brought out, or to have justice done to it, must be always echoed by the general movement of the form of verse which it selects as its vehicle; that is only a very elementary and a very small part of the matter. Verse, in its perfect ideal, is, although the artistic, at the same time also the natural and spontaneous expression of whatever so utters itself. The thought takes that shape because it would not have full and satisfactory expression in any other. The music of the verse is necessary for the complete expression of the thought. It requires not only certain words, but those words so arranged as that the expression is aided by every cadence, and by the vocal character of every syllable in its particular position. If it were not so, there would be no sufficient reason why the restrictions of verse should be submitted to, or rather clung to, as they are, by the poet. What can alone be held to prompt and to justify this peculiar mode of expression is, that it is his only adequate one. The ideal, it is true, is never to be absolutely attained in the actual. Even words, the airiest and most delicate of all the ministering spirits of the human mind, can but partially satisfy its desires and perform its behests. But the art of the poet consists in making them obey him as far as possible; for they are the only instrumentalities by which he can work his enchantments. And harmonious verse is as it were, the crowned and kingly state of words; it is the highest triumph of expression. It is what the flower, with its blaze of coloured beauty, is to the stalk and the green leaves. Prose composition is at the most but a sort of walking or running, the main or sole purpose of which usually may be said to be merely to get to the point at which it is to terminate; verse is a dance, solemn or gay, which is itself an end and a delight, and every one of whose balanced and swimming movements should be instinet with the spirit of song and of passion.

RHYME NOT POETRY.

Most men by numbers judge a poet's song,
And smooth or rough with them is right or wrong:
In the bright muse, tho' thousand charms conspire,
Her voice is all these tuneful fools admire;
Who haunt Parnassus, but to please the ear,
Not mend their minds, as some to church repair,
Not for the doctrine, but the music, there.
These equal syllables alone require,
Though oft the ear the open vowels tire
While expletives their feeble aid do join,
And ten low words oft creep in one dull line,
While they ring round the same unvaried chimes,
With sure returns of still-expected rhymes.
Where'er you find "the cooling western breeze,"
On the next line it "whispers through the trees;"
If crystal streams "with pleasing murmurs creep,"
The reader's threatened (not in vain) with "sleep;"
Then at the last and only couplet fraught
With some unmeaning thing they call a thought,
A needless Alexandrine ends the song,
That, like a wounded snake, drags its slow length along.
Leave such to tune their own dull rhymes and know
What's roundly smooth or languishingly slow,
And praise the easy vigour of a line,
Where Denham's strength and Waller's sweetness join.
True ease in writing comes from art, not chance,
As those move easiest who have learned to dance.

POPE.

LESSON III.

LYRIC POETRY.

1. THE kind of poetry which has been produced in every language in the greatest quantity is the same that has already been described as the oldest kind, and the original of all others, namely what is called Lyric poetry. It is at once woven out of those elements of thought and emotion which are most generally diffused among men, and is the least under bondage to rules. It is therefore the poetry that is both the most natural, or most easily produced, and the most widely enjoyed. In its simplest form, lyric poetry, as we have seen, is little more than

pure song—a few words strung together with scarcely any farther aim than that they should chime to the melody. Examples of this are still plentiful, both in our nursery and popular rhymes, and in the refrains or burthens of many of our old songs. Anything will do for a song or ballad, that will only sing; the commonest tissue of thought or sentiment in the most inartificial words. It may be of any measure; and of any length, from a single verse or stanza to as many as the subject or story may require or will bear. It may be either sad or gay, or anything between the deepest tenderness and the most extravagant comic humour. And all hearts feel the charm of this kind of poetry. It is indeed the only kind which the mass of mankind enjoy or understand.

2. Song and ballad poetry, accordingly, has sprung up in every country almost like the wild-flowers by the wayside. Very little of all of it that has been produced has ever got written down; yet it is wonderful how long it will often live in its unrecorded state, preserved only in the memories and on the lips of the people. The language, it is true, will usually, in such circumstances, undergo some modification; but the substance of the poetry remains. The popular songs and ballads of one age are, at least, the offspring of those of the preceding age, even as those who recite them now are the sons and daughters of those who recited them then. This literature, if so it may be called, only perishes with the spirit and system of social life out of which it grew, and the substitution, whether suddenly or gradually, of quite another phase of civilization.

The poetry that is committed to writing is, for the most part, a thing of another kind from this altogether. It is the wild-flower transplanted to the garden, and trained by all the resources of art. The difference between this poetry of cultivation and the unwritten popular poetry of which we have been speaking is as great as that between the man of the woods and one who has been born and brought up in a civilized country.

3. Of the cultivated lyric poetry of the old Greeks and

Romans, the whole of whose literature has so greatly influenced that of the modern European world, a good deal in various styles has come down to us. We have in Greek, to mention only a few of the more celebrated names, the odes of Pindar, the war-songs of Tyrtæus, the love-songs of Anacreon, the precious remains of Sappho and of Simonides, and the choral odes interspersed in the tragedies of Æschylus, Sophocles, and Euripides. In Latin, we have at least the odes of Horace. In like manner, the literature of every modern language of Europe abounds with lyric poetry addressed to the most cultivated tastes of the time in which it was composed. Some of our English lyric poems are among the most renowned productions in the language; such as Spenser's Epithalamion on his own marriage, Milton's Hymn on the Nativity, Dryden's Alexander's Feast, Collins' Ode on the Passions, Gray's Bard, and Progress of Poesy, Coleridge's France and Dejection, Wordsworth's Platonic Ode on Immortality, Campbell's Mariners of England and Battle of the Baltic, Byron's Isles of Greece, Shelley's Lines to a Skylark; not to mention many songs of exquisite beauty with which almost every one of our great poets has enriched his native tongue, from those scattered through the plays of Shakspeare, and of Beaumont and Fletcher, to those which we owe to Burns, and Moore, and Hood, and Tennyson.

In its cultivated forms likewise, indeed, as well as in what may be called its wild or native state, lyric poetry is by far the most abundant of all poetry. It is to the other kinds of poetry, which have all been elaborated out of it, what the general atmosphere is to the various distinct gases which are found in it and may be extracted from it. Nor is there any resource of the poet's art for the exercise of which it does not afford room and fit occasion, ranging as it does through every variety of style and character, from the utmost simplicity to what is most intense in passion and most daring in expression. There is no other kind of poetry that can venture so far in either direction.

4. In some respects, however, the lyrical poetry of

what we have called the uncultivated kind is the most interesting. It is for the most part simple to the point of rudeness. But that nowise unfits it for its great purpose of acting upon the popular heart and mind. There can be no question as to the extent to which it has done that among every people. It has not only been everywhere the earliest national literature, but has usually continued to be the only literature of the great body of the community long after the growth of other kinds addressing themselves to the more educated few. All national history, in particular, that has shaped itself into words, has in the first instance assumed the form of songs and ballads. The early Roman history, as we have it in Livy and other writers, is apparently almost wholly founded upon such popular rhythmical compositions, which occasionally the regular historian has not refrained from referring to as his authority. Even so the English and Scottish historians of the middle ages, Huntingdon, Major, and others, quote or specify the old ballads circulating among the people as their sources of information regarding the exploits of Hereward, Wallace, and other national heroes. Popular lyric poetry of this historical and political kind must be understood to be what was chiefly in the mind of the Scottish patriot, Fletcher of Saltoun, when he pronounced his famous aphorism as to the true secret for ruling a community:—"Give me the making of a people's songs and ballads, and let who will make their laws." Even since his time the most remarkable effects upon the course of national affairs have been repeatedly produced, both in our own and in other countries, by a few rhymes which, giving expression to the general sentiment, and sustained by being united to a characteristic and, above all, an easily caught musical air, have, as it were, collected men's scattered sympathies into a chorus drowning and bearing down all before it: witness the song of the "Thirty thousand Cornish boys," on occasion of the trial of the seven bishops; the Marquis of Wharton's song of *Lillibullero*, by which he is said to have boasted that he had driven James II. from his throne; and Rouget de Lille's Chant of *La Marseillaise*, which gave such an impulse to the first French Revolution. But the power of its songs thus to stir and move a people upon particular occasions is perhaps exceeded in importance by their influence in permanently moulding the national character; and in that popular poetry of every kind takes its share, love-songs and comic songs as well as ballads, historical, political, and military. As they are all the product of the national character, so they re-act upon it. The soil is manured and strengthened by that to which it has itself given birth and being. Thus it is, for instance, that the general spirit of affection for and of pride in the sea service has been unquestionably heightened among Englishmen of all classes by the songs of Dibdin; and perhaps even the rich aggregate of qualities that makes up the English sailor himself, about the most ideal character now remaining in the civilized world, may not be unindebted for something of the tenacity of adherence with which its various elements continue to hold together as perfectly in our disenchanted day as if heaven and earth were still all poetry, to the same admirable compositions.

5. Seldom committed to writing when first produced, much of it, indeed, having appeared in most countries before the art of writing was generally known or practised, and never having been designed for what may be called a literary existence or position, this popular poetry is not treated quite naturally or fairly when it is collected into books for the purpose of being stored up in libraries. That is not the mode of preservation to which it is adapted. The case is somewhat similar to that of the savage transferred in his mature age to a civilized life. When popular poetry, in fact, begins to be thus gathered and garnered, it is a sign that it is dying out. What has been already produced is getting forgotten, and the power of producing more is going or gone. The genuine and cordial enjoyment of it, amounting in both the poet and his hearers to a full faith in all that it embodied or expressed, no longer exists, but has given way to doubt or incredulity or indif-

ference. New tastes, as well as a new philosophy, have sprung up. What used to be listened to with belief and passion is now read only in a spirit of critical curiosity. Probably scarcely any poetry has been produced in England that has rooted itself in the popular heart, and lived the old natural life of transmission from one age to another chiefly or entirely through oral recitation, or being learned and inherited by every new and rising generation from that passing away, since the civil wars and the overthrow of the monarchy in the middle of the seventeenth century. That convulsion seems to have closed the cycle of civilization to which such poetry properly belonged, or in which it was of spontaneous growth. Before the end of the same century the practice of presenting it to the general reading public as so much curious literary treasure indicated the feeling and the fact that its era was past. What had attracted no attention, nor had been thought to be worth any, while it was to be found everywhere in plenty above ground, had begun to be prized since it had become a fossil, and was only to be obtained by some research and labour. It now appealed to the imagination as a vestige or shadow of a social state which had passed away for ever.

6. One of the volumes of what is called *Tonson's Miscellany*, originally edited by Dryden, and published before the year 1700, contains a considerable number of old ballads. Not long after the beginning of the next century, the eighteenth, various professed collections of old songs and ballads appeared both in England and Scotland; such as Watson's collection, at Edinburgh, in 1706; another at London, in three volumes, in 1724; and Allan Ramsay's *Tea Table Miscellany*, (which contained, however, also many avowedly new songs, as well as some that were probably new though pretending to be old) at Edinburgh, in the same year. These publications, however, must be considered to be intended merely, or at least mainly, for the use of the uncritical reader, who cared for the songs and ballads for their own sake, and without any feeling or thought

of the adventitious interest which they derived from their connexion with a bygone time and state of things; they were still to a certain extent the household literature of all classes, and the volumes in which they were now presented were acceptable simply as convenient repositories of a lore that had not ceased to be everywhere more or less familiar, though beginning to lose that hold upon the memory which used to be its sufficient preservative. The song-books and ballad-books which now appeared were, in fact, artificial substitutes for that old natural support.

7. The proper era of the practice of collecting and reproducing the remains of our popular national minstrelsy in a distinctly literary spirit did not commence till some years after the middle of the century with the first publication of Bishop Percy's famous work, the "Reliques of Ancient English Poetry." By that date our old songs and ballads had fallen into general forgetfulness. They were recognized, in so far as they were remembered or known, not to belong to the present time, but to be only a voice or memorial of the past,—to be nothing more than "ancient reliques," as Percy's title-page described them. As such, to the multitude they had become as nothing. This new work, accordingly, in which they were collected, was no longer simply a song-book or ballad-book for everybody who could read or sing, but addressed itself specially to readers of the more cultivated class, whom it aimed at interesting, in part at least, through their critical appreciation and antiquarian curiosity and sentiment. And it has been followed by a long succession of other collections, all formed upon the same principle;—the most celebrated, and upon the whole the most important, being "The Minstrelsy of the Border," by which Sir Walter Scott did for the old popular poetry of Scotland much the same service that Percy had done for that of England about half a century before.

YE MARINERS OF ENGLAND.

Ye mariners of England
That guard our native seas;
Whose flag has braved a thousand years
The battle and the breeze.
Your glorious standard launch again
To match another foe!
And sweep through the deep,
While the stormy winds do blow;
While the battle rages loud and long,
And the stormy winds do blow.

The spirits of your fathers
Shall start from every wave!
For the deck it was their field of fame,
And ocean was their grave;
Where Blake and mighty Nelson fell,
Your manly hearts shall glow,
As ye sweep through the deep,
While the stormy winds do blow;
And the battle rages loud and long,
And the stormy winds do blow.

Britannia needs no bulwark,
No towers along the steep;
Her march is o'er the mountain waves,
Her home is on the deep.
With thunders from her native oak
She quells the floods below,
As they roar on the shore,
When the stormy winds do blow;
When the battle rages loud and long
And the stormy winds do blow

The meteor-flag of England
Shall yet terrific burn,
Till danger's troubled night depart,
And the star of peace return.
Then, then, ye ocean warriors!
Our song and feast shall flow
To the fame of your name,
When the storm hath ceased to blow!
When the fiery fight is heard no more.
And the storm has ceased to blow.

Campbell.

LESSON IV.

DRAMATIC AND EPIC POETRY.

1. Of the other two great forms or modifications into which we have supposed poetry to have branched forth from its primitive lyric stem, Dramatic poetry may be held to have sprung more especially from the song and Epic from the ballad. Even where it does not prompt to dancing or to any other kind of corporeal movement, a song readily takes the shape of dialogue: many songs are dialogues and nothing more; and dialogue is really the essence and the sole distinguishing characteristic of the drama. The drama, when it first came to be anything more than a song, was merely a song in dialogue, with the speakers severally represented. Among the Greeks the lyrical origin of the drama continued, besides, to the last to be forcibly marked and commemorated by the purely and intensely lyrical character of the choral odes. And the drama of the ancients, also, both that of the Greeks and that of the Romans, was always throughout in verse—their comedy as well as their tragedy. A drama in prose would have seemed to them as great a monstrosity and absurdity as a song in prose. The tragic Æschylus, Sophocles, and Euripides, and the comic Aristophanes and Menander, among the Greeks; and, among the Latins, the comic Plautus and Terence, as well as the tragic Seneca, all wrote nothing except in verse.

2. Even in modern European literature, all dramatic writing, both tragic and comic, was everywhere originally in verse. Regarded as a species of poetry, it naturally assumed the ordinary form of poetry. This was the case with the drama in England, as well as in Italy, in Spain, in France, and in Germany. Our old Mysteries, or Miracle Plays, as they were called, were all in rhyme. So are what are accounted our two oldest regular comedies, "Ralph Roister Doister," and "Gammer Gurton's Needle." The tendency of the drama, however, to throw off the restraint of the poetical form, was early evinced by its exchange of rhyme for blank verse. What is regarded as our

earliest English tragedy, that of "Gorboduc," (otherwise called "Ferrex and Porrex"), which appeared soon after the middle of the sixteenth century, is also one of the earliest specimens in the language of verse without rhyme. From this time our English tragedies have been generally in blank verse, although the fashion of rhyme, even in dramatic writing, was restored for a time by Dryden and other imitators of the French school in the latter part of the seventeenth century. But in more recent times even our tragedy has repeatedly discarded verse altogether, and taken to plain prose. And prose has long been more common than verse in our comic drama, as it has also been in that of both France and Germany. The course that this matter has taken is natural enough: the first prose that was employed in dramatic writing was only verse somewhat freer or less regular than in other poetical compositions; the more vivid imitation of the real which acting implies, as compared with simple reading or recitation, seemed to justify or to demand this; then the irregularity was carried so far as to allow the dialogue, though generally in verse, to drop wholly into prose on certain exceptional occasions; then, finally, as is apt to happen with everything, at least in any descending movement, the exception usurped the place of the rule. It may be questioned, however, in how far dramatic composition in relinquishing the form of verse is more faithful to its true nature and principles than it is to its origin and lineage. It may be said, indeed, that the prose drama is a more exact representation of real life than that which is cast in the mould of verse; and so, no doubt, it is; for people in real life do not speak in verse, but in prose. The very definition of the artistic, however, in all its manifestations, is that it is never simply a representation of the real, but always also, more or less, a transformation of it.

3. The prose drama would seem to stand in the same relationship to poetry that prose narrative writing does. That is to say, it may be poetical, but cannot properly be called poetry. It is to poetry only what an artistically-composed history or novel is. As the Drama arose out

of the original lyric constitution of poetry under the predominance of the element or spirit of dialogue, so under that of the narrative element was evolved the Epic. An epic poem is nothing more than a more extended and more artificial ballad. A subject that would furnish out a dozen ballads may be all comprehended in a single epic. The first of all epics, the Iliad of Homer, has been maintained by some modern critics to be actually only a number of originally distinct ballads strung or tacked together, which were possibly or probably not even all composed by the same poet. But if this were really so, the Iliad would not be an epic at all, or at best would be one only by accident. For it is indispensable to that, as to every other artistic production, that it shall have been all conceived both by one mind and as one thing.

4. The antiquity of the Iliad and the Odyssey so far transcends all history that external evidence in regard to their origin is entirely wanting. They had already been in existence for many generations at the date of the earliest notices of them that have come down to us. Long before the commencement of that Greek literature of which we know the age and the history, the Homeric poetry had certainly acquired a wide popularity. This goes to make the question of its authorship a dark and difficult one in various ways. It is somewhat like the question of the origin of language itself. But surely we very slightly reduce the difficulty by merely getting rid of so much of it as we should be relieved from by the supposition that the poetry, when first produced, wanted the epic unity which we now find in it. That is not the chief thing that makes it so wonderful. The marvel would be scarcely less if its claim to the epic character were given up. The great fact would still remain, that a large body of the most remarkable poetry in the world had been produced in an age long preceding what, but for such phenomenon, we should have regarded as the birth of literature in the language to which the poetry belongs—we might almost say, indeed, the birth of civilization, seeing that apparently even the art of -iting was not then known among the Greeks: not only

is nothing of the kind ever mentioned or alluded to in the Homeric poetry, with all its abounding knowledge and universal sympathy, and minute, as well as multifarious, as the picture is which it spreads before us of what must be supposed to be the social condition out of which it proceeded, but some things seem positively to imply the non-existence of alphabetic characters. Those traces in the poems, on the other hand, which have been cited in support of the position that they could not have been originally composed in the form in which we now have them, may all be otherwise accounted for. Some such evidence might probably be produced against any long poem whatever. It would only prove at the most, in any case, that the poet had been now and then oblivious or negligent, or, from some other cause, not always perfectly consistent with himself. The Homeric poetry, besides, cannot be supposed to have descended through its existence of probably not many fewer than thirty centuries without having sustained some injuries from time, or, more especially before it was committed to the guardianship of writing, having possibly also contracted some additions to its original substance.

5. As for the laws of epic poetry, which the Iliad as we have it is accused of sometimes violating, they may be said to be one and all founded upon or derived from itself. The science of poetical criticism is mainly a systematic digest of the practice of Homer. Its rules and principles have been from the first little more than what his example has been believed to sanction. If the Iliad is not, or was not originally, a true epic, it has nevertheless served as the grand model and standard for all the epic poetry that has since been produced.

6. By the Greeks themselves the poetry of Homer was regarded as standing apart from all other poetry. With them others were poets, but he was *the* poet. Nature herself was not greater than Homer. He and it were the same. His poetry belonged to nature, and was a part of it, as much as anything in the peopled earth or the covering sky. And certainly there is no other poetry that is at once so ideal and so real. Whatever he describes he paints to the sense as well as to the

mind. We see his battles and hear his harangues. Yet at the same time there is no poetry that is farther from being a mere literal transcript of reality. Everything in it is transfigured and glorified. While it is all so like truth, it is still liker creation. It is the most glowing of all poetry, and at the same time the most melodious. Nowhere else is passion either so fiery and tumultuous, or so rhythmical and imaginative. And ever, the higher the passion mounts, the more musical is the resounding verse. It is as if the power of passion only furnished fuel to that of song; or as if they were throughout wrestling together and contending for the mastery, and, the fiercer their embrace, were only the more thoroughly fused into one. And no other poet has so forgotten himself in his theme as Homer has done. It seems almost to sing itself, that wondrous "tale of Troy,"—so divine, and yet so human too,—so life-like and at the same time so dream-like—so crowded with both the natural and the supernatural, —which has in his magic numbers so charmed so many generations.

7. The literature of Rome is for the greater part a reflection from that of Greece; and the Æneid of the Latin poet Virgil is a very pale reflection of the Iliad. The Iliad and the Odyssey have been discriminated by being compared respectively to the sun in his meridian height and in his decline; such poetic effulgence as we have in the Æneid may be likened to the borrowed light of the moon. It is a delicate and tender light, not without its own peculiar beauty, though cold and lifeless. By many minds, and by most, perhaps, in some moods, it is preferred to the glow and fervour of the other. As Pope has sung:—

"So when the sun's broad beam has tired the sight,
All mild ascends the moon's more sober light:
Serene in virgin modesty she shines,
And unobserved the glaring orb declines."

And Coleridge tells of

"a climate where, they say,
The night is more beloved than day."

The charm of the Æneid lies in its being so perfectly that which it is. It is "a gem of purest ray serene." It is a sky without a cloud, though only a night-sky. But the imitation of Homer is, after all, but the imitation of gold in silver—

> "'Tis Greece, but living Greece no more!
> So coldly sweet, so deadly fair,
> We start, for soul is wanting there."

8. Of modern European epics the "Paradise Lost" of our own Milton is the most renowned and the greatest, if it is not, indeed, to be accounted the first and noblest of all epics. It differs from the two great epics of antiquity, and also from most modern poems of the same class, such as, for instance, the "Lusiad" of the Portuguese Camoens, and the "Henriade" of the French Voltaire, (if this last deserves to be reckoned among great poems), in that its subject is not specially national. In this respect it resembles the great Italian epic, the "Jerusalem Delivered" of Tasso. For the narrowness of nationality both Tasso and Milton have substituted the wider bond of religion. Theirs are not epics of Italy or of England, but of Christendom. Such a constitution of the epic would have been hardly possible for antiquity. With Greece and Rome religion was little or nothing except as associated with or in subordination to race. Even among the Hebrews it was the same. The sentiment of which Tasso and Milton have taken advantage has been wholly the product of Christianity (from which, however, it has also been caught to some extent by the Mahometan populations, impressed upon them mainly by the long contest for supremacy between the two faiths of which what has been called "the world's debate" of the Crusades was only a remarkable and exceptional portion, that, namely, in which Christianity became for a time the assailing power, and attempted to roll back the tide of Mahometan aggression and conquest). But Milton is the epic poet of Christianity in a much deeper and more comprehensive sense than Tasso. The spirit of his poem may be most correctly described by the term Biblical; it is drawn equally from both Testaments.

And its theme is universal as humanity, or indeed we may say as the universe itself; embracing, as it does, earth and heaven and hell, and not only the creation and fall of man but the rebellion of the angels and the origin of evil and of sin, and stretching not only over all time but into the depths of past and coming eternity. Nor has any poetry in any tongue more of the soul of divinest song than Milton's: it is a world of richest music; and majesty and beauty walk about in it like his own happy pair in their glorious Eden.

9. Most of the subordinate forms of poetry may be regarded as derivations from or modifications of the epic. Almost the only kind that can be classed with the drama is Eclogue or Pastoral. That, too, as well as dramatic poetry, is frequently in dialogue. All narrative poetry plainly comes under the head of the epic; and by far the greater part of all poetry is more or less of a narrative character. Even what is called a philosophical, or didactic, or descriptive poem is rarely without some thread of narrative running through it, if it were no more than so much as to tell us what it was that gave occasion to the course of the reasonings or reflections. Any such poem is only an epic with the narrative reduced and the other ingredients exaggerated. And it is in poetry as it is in prose: while great epics are the rarest of all poems, narrative poetry is of all poetry the most plentiful; just as nine-tenths of all the prose that is written is narrative, and yet great histories are almost as few in number as great epics.

G. L. CRAIK.

WHAT IS PRAYER.

PRAYER is the soul's sincere desire,
  Uttered or unexpressed;
The motion of a hidden fire,
  That trembles in the breast.

Prayer is the burden of a sigh,
  The falling of a tear;
The upward glancing of an eye
  When none but God is near.

Prayer is the simplest form of speech
  That infant lips can try;
Prayer the sublimest strains that reach
  The Majesty on high,

Prayer is the Christian's vital breath,
  The Christian's native air;
His watchword at the gates of death—
  He enters heaven by prayer.

Prayer is the contrite sinner's voice,
  Returning from his ways;
While angels in their songs rejoice,
  And cry, "Behold, he prays!"

The saints in prayer appear as one,
  In word, and deed, and mind;
While with the Father and the Son,
  Sweet fellowship they find.

Nor prayer is made on earth alone:
  The Holy Spirit pleads;
And Jesus on the eternal throne
  For mourners intercedes.

O Thou! by whom we come to God,
  The life, the truth, the way;
The path of prayer thyself hast trod:
  Lord, teach us how to pray.

As fail the waters from the deep,
  As summer brooks run dry,
Man lieth down in dreamless sleep,
  His life is vanity.

Man lieth down, no more to wake,
  Till yonder arching sphere,
Shall with a roll of thunder break
  And nature disappear.

Oh! hide me till Thy wrath be past,
  Thou, who canst slay or save!
Hide me where hope may anchor fast.—
  In my Redeemer's grave!

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The work will appear as soon as possible after the Population Tables of the Census of 1851 have been published, and at a moderate price, so as to make it available to all classes of teachers.

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